Preservation Research and Development

Round Table Proceedings
September 28-29, 1992

Library of Congress
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Edited by Carrie Beyer
National Preservation Program Office

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PRESERVATION RESEARCH AND DEVELOPMENT:

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TABLE OF CONTENTS

2

HIGHLIGHTS OF THE ROUND TABLE ON PRESERVATION RESEARCH AND DEVELOPMENT

LINDA NAINIS, *PROTEXT*

In a broad sense, the mission of the Library of Congress Round Table on Preservation Research and Development was to "define a new domain, a new area of competence in a field that we should call preservation science," said Winston Tabb, Library of Congress, in his welcoming address. New technologies, ongoing research, and appropriate methodologies are molding and shaping the preservation of library collections for future generations.

The goal of the Round Table was to stimulate awareness of the field, its progress to date, and foster the opportunity for dialogue about its future. In the process, participants were challenged to search for "ways to forge cooperative, creative links between and among fundamental scientists and administrators who are interested in preservation," said Chandru Shahani, Library of Congress, principle planner of the two-day meeting.

Many participants, having concentrated on analyzing individual objects, had come to the conference calling themselves "conservation scientists," or had viewed "preservation from a conservator's perspective," in the words of Peter Waters, Library of Congress. At the Round Table's conclusion, many left with the idea of developing scientific and engineering methods that will examine the long-range preservation of entire collections.

Predicting the longevity of collections is no easy task, particularly for scientists, as Paul Whitmore, Carnegie Mellon University, emphasized in his keynote address. Intrinsic to the nature and training of scientists is the habit of finite investigation. Objects are brought very close in order to understand subtle details. The danger of such close examination, however, is that overall perspective can be lost. Whitmore called this phenomenon "the myopia of preservation research." It interferes with the ability to see detail in objects that may be broader than the immediate focus of study.

The myopia not only pertains to the object in space, says Whitmore, but also in time. Thus, the ability to project into the future is adversely affected. That is unfortunate, because a long-range perspective is necessary for preservation science. In order to compensate for the difficulty of projecting into the future and predicting the effect of aging over time, scientists have developed accelerated aging techniques. Accelerated aging, however, offers only an oblique model, an imperfect tool, Whitmore said.

SESSION I: INTRODUCTIONS, DISCUSSION, AND BRIEF RESEARCH REPORTS

The first session gave participants the opportunity to introduce themselves. It provided the forum for a number of prominent research organizations to report on areas of scientific inquiry, and to show the breadth and variety of current research in preservation.

The Rijkarchiefdienst, the National Archives of the Netherlands, was represented by Preservation Officers Ted Steemers and Gerrit de Bruin. Steemers and de Bruin spoke of a wide variety of ongoing investigations, including the evaluation of mass deacidification methods, conservation of acid paper materials, the use of permanent paper, reinforcement of brittle papers, analysis of effects and energy costs of various air filtration systems, among other research topics.

Marion Mecklenburg said the Smithsonian's Conservation Analytical Laboratory (CAL) conducts research on the conservation of traditional materials (oils, cellulose, materials in paper) and materials that are found "in museums such as the National Air and Space Museum where we have nothing but modern materials, a big problem." Much of CAL's research emphasizes the physics and mechanics of conservation. They are "looking at the effects of environmental factors on the mechanical or stress development in paintings...and...photographic material," said Mecklenburg. Investigative work relating to how changes in temperature and humidity create physical stress were reported on by Mark McCormick-Goodhart, and David Erhardt.

Yale University' Paul Conway, and Cornell University's Anne Kenney introduced their two research projects on digital technology that were funded by the Commission on Preservation and Access.

Informal discussion topics began to emerge, some from the remarks presented in the welcoming and keynote addresses. One issue clearly dominated: Exactly what is at the heart of preservation science? Scott Bennett, Johns Hopkins University, emphasized the importance, not of technical research alone, but of economic analysis and modelling to investigate how preservation techniques should be employed. "At heart," said Bennett, "preservation is an investment activity." Other administrators, including William Studer, Ohio State University, and Martin Runkle, University of Chicago, voiced concern, as well, that preservation funds be spent as wisely as possible. Otherwise, "I worry that the price tag will prove near insurmountable in times of protracted retraction," said Studer.

Paul Conway, Yale University, stressed the social science component of preservation research. Preservation science, he said must be about "organizational behaviors that are centered around the creation, acquisition, and selection of information sources...and such issues as the sociology of learning and scholarship...within a society that does not value its own history." Leslie Smith, National Institute of Standards and Technology, postulated that preservation science, at its heart, is materials science. Materials science is a discipline that can "provide fundamental data on the inherent stability of materials, the interaction of materials with their environment..." Smith acknowledged that a sizeable amount of anecdotal evidence and data on samples exists. Unfortunately, this data, he said "cannot be well-characterized as being representative of a larger population." Therefore, what is needed is for the "materials science community [to] develop the fundamental data on materials that is of interest to us." And furthermore, preservation science needs "qualitative scientific and engineering models on the behavior of entire systems," said Smith, and "one example of that is the economic trade-offs, as Scott Bennett was talking about."

The subject of accelerated aging as a method to predict the longevity of materials met with general dissatisfaction. Whitmore, in his keynote address had said, "it is improbable that the exact combination of degradative mechanisms can ever be duplicated in any accelerated aging tests, and one hopes to at least produce the effects of the important deterioration route." William K. Wilson, retired National Institute of Standards and Technology (NIST) and currently guest worker at the National Archives, quipped: "to say accelerated aging is an exact science is like evaluating the shelf life of eggs by dropping them in boiling water for five minutes." Klaus Hendriks, National Archives of Canada, recalled that the Image Permanence Institute likes to explain the pitfalls of accelerated aging by the following example: "if you put an egg in boiling water, you get a boiled egg; or if you let it sit at room temperature—which is called natural aging—you get a rotten egg; number three, if you sit on it for thirty days, you get a chicken." In other words, accelerated aging works best when the material is simple. With complex materials, you don't always know whether you've got boiled eggs, rotten eggs or chickens. To complicate matters further, it was generally agreed that to properly interpret the results of accelerated aging tests, natural aging comparisons are necessary; unfortunately, natural aging comparisons do not exist for new materials.

Preservation scientists must be concerned with modern as well as traditional materials. Libraries of record, like the National Library of Medicine, are "bringing [modern material] into our collection" and said Margaret Byrnes, "we have to take the responsibility for preserving that material, as difficult as it may be, as seriously as we do our responsibility for paper records." Three categories were discussed in the reporting sessions that followed: digital technology, paper-based materials, and photographic images.

SESSION II: DIGITAL TECHNOLOGY

The digital technology session, chaired by Basil Manns, was oriented toward applied research, unlike the sessions about paper and film that reported on fundamental scientific research activities.

Judith Russell, Government Printing Office, described a program called "life cycle management of information." This program of archiving tapes and disks used to complete printing jobs, she believes, provides significant potential as a preservation approach.[1]

The approach has allowed the publisher and printer to design the publication once, capture it the first time, and continue to use the digital master throughout the whole life of the publication, essentially adapting a print-on-demand capability for some publications. Working from the digital printing masters is advantageous because the masters contain all of the original formatting, graphics, table layout, and illustrations exactly as it appeared when it went to press. This original typesetting is important to keep, Russell said, because "people design type and lay out pages to convey meaning...We tend to lose [that meaning] when we [go] back to the ASCII text." Russell admitted, however, that additional mechanisms and standards are needed to maintain the usability of

these digital files far in the future.

The problem of preserving existing digital media is difficult because the technology is still evolving. Mike Rubinfeld, NIST, had stated earlier that it has not been determined exactly what the lifespan of polycarbonate disks are, maybe 25 years, maybe as much as 100. But the predominant disk media substrate has changed a number of times and can be expected to change more.

Thomas Bagg, NIST, said that the lifespan of materials is not the main issue. Even high estimates of lifespan are not reassuring in light of intermediate-term equipment obsolescence expectations. How long the media will remain usable is not merely a materials problem, Bagg pointed out, but a systems problem. What we need are "technology migration strategies," Charles Dollar, National Archives and Records Administration, said, in order to deal with the problem of technical obsolescence and data degradation.

The necessity of "refreshing" digital tapes to preserve them drew much attention. It was easy for administrators to imagine a situation where there was not enough money or time to keep up with the refreshment scheduling. Jan Merrill-Oldham, University of Connecticut, voiced the pessimism of many in the preservation community who dreaded a period when resources were scarce, such as in wartime, depression or other national emergency, or just when budgets are tight, when other budget priorities are competing, or when there is a lack of interest in infrequently-used material.

Proponents of converting to digital said that only a small percentage of the information that our culture produces has enduring value anyway. Moreover, it is simply necessary to build an infrastructure that has the responsibility to refresh. George Thoma, National Library of Medicine, suggested that national libraries can take the lead in creating organizations that handle this responsibility well. During the transition period, one must keep an analog back up. Above all, indexes should be archived on computer output microfilm or on paper.

The challenges and commitments involved in converting library holdings to digital format involve major management considerations. These had been described during the first session by Anne Kenney, Cornell University; and Paul Conway, Yale University. Gary McCone, National Agricultural Library further elaborated upon and gave numerous examples of considerations such as (1) the cost-effectiveness of producing good quality images; (2) how to realize accessibility, the real promise of digital technology; (3) how to collaborate with vendors; (4) how to deal with the necessity of relying upon commercially-available technology; and (5) how to utilize standards.

Standards were mentioned repeatedly as absolutely critical to the success of digital technology. Bagg and other digital technology experts emphasized, for example, the need for a standardized indexing strategy, because indexes are so valuable as access tools. The discussions revealed that, unfortunately, the field of digital technology is not yet highly standardized, despite an enormous amount of work that has gone into creating and revising standards.

SESSION III: MASS PRESERVATION OF PAPER

In the session on mass preservation of paper, presentations from four major research organizations—the Library of Congress, the Getty Conservation Institute, the U.S. National Archives and Records Administration, and the National Archives of Sweden—gave a sense of the breadth and scope of preservation research projects that are being conducted in deacidification, environmental conditions and storage, and paper chemistry.

Chandru Shahani described research at the Library of Congress including investigations of environmental effects on paper longevity and studies of the benefit of using boxes or encapsulation envelopes to create microenvironments. Don Sebera provided a description of the Library of Congress' year-long project to evaluate currently-available mass deacidification technology. During the study period, the Library of Congress, Swiss National Library and Swiss Federal Archives formed an agreement to share information about their research on mass deacidification.

The Getty Conservation Institute's conservation scientist, James Druzik, described noteworthy projects. He reported that projects are grouped into four major areas of concentration: environment, conservation materials and methods, new technologies, and architecture. Druzik referred to a 1992 publication entitled "Research Abstracts of the Scientific Program," that provides a description of the full range of work that is going on at the Getty Conservation Institute.

A kaleidoscope of research activities are ongoing at the National Archives and Records Administration, said Lewis Bellardo. Many recent projects were

directly related to the challenges of moving to the new facility, called Archives II. Like the Library of Congress, the National Archives is interested in the effect of microenvironments, with shrink wrapping as one of those kinds of microenvironments," Bellardo said. "We have the very practical problem of moving hundreds of thousands of volumes, some of which are in very fragile condition..." He said that the staff has been busy designing , fabricating and contracting for special housings for oversize, odd-shaped and fragile materials, and as part of this effort, has "adopted the technique of shrink packaging as a very inexpensive way to provide extra protection for these materials." In addition, researchers have been evaluating the stability of "a whole range of sealants and coatings and various materials that will be used, or might be used...in Archives II...in conjunction with exhibits." Among other subjects of research, the National Archives has been evaluating the storage equipment and shelving that will be selected for Archives II, and has studied various methods of examining extremely low levels of pollutants in order to monitor the building's filtration system on a continuing basis.

A research coordinator from the National Archives of Sweden, Ingmar Fröjd, described research and development projects on deacidification, environmental conditions and the storage and production of fine paper. Most research on paper preservation in his small country, he explained, is contracted out and sponsored collaboratively as joint projects with a number of public institutions that gathered together in the national effort of research and investigation. Fröjd, who works closely with Swedish paper industry experts, said he has become convinced that high lignin content does not necessarily reduce aging stability if the paper is alkaline.

The issue of whether it is possible to create a permanent paper with lignin as a component is of great importance to the Canadian paper industry, said Klaus Hendriks, National Archives of Canada. Like the Swedish companies, Canadian firms claim they have created new technologies that enable them to meet the quality level sought for permanent paper, but in a way that does not have the mechanical pulp limitations of standards now in effect.

Most preservation experts believe that lignin caused, at least in part, the brittle paper problem. Lignin is present in the non-cellulose fiber of paper made with mechanically—processed ground wood, a process begun by Charles Fenerty in Canada in the mid 1800's. During the discussion period, Hendriks questioned the role of lignin in paper deterioration, saying, "The industry immediately makes a distinction between optical permanence and mechanical permanence, and we know that it leads to yellowing of paper and almost all the literature is dedicated to that. But the industry still maintains that it has little effect on the mechanical permanence, the mechanical strength of paper."

William K. Wilson disclosed that the lignin controversy erupted in a meeting of the ASTM D-6, Paper and Paper Products meeting the week before the Library of Congress Round Table. Susan Lee-Bechtold, National Archives and Records Administration, added that she has been testing to measure lignin content and how it affects the permanence of paper. Lignins do vary in stability (by the species of wood), Wilson conceded, and Swedish or Canadian pulp may have greater stability that one would think. More data is needed, Wilson asserted, because a serious challenge to the records situation would be created, he believes, if mechanical pulp were added to permanent record paper.

SESSION IV: PHOTOGRAPHIC IMAGE PRESERVATION

Presentations from the research directors of the National Archives of Canada and the Image Permanence Institute described an impressive range of work that is largely concerned with photographic image preservation.

Klaus Hendriks, National Archives of Canada, provided illustrations of the type of deterioration that occurs to photographs with aging and described the chemical changes that occur at the molecular level when silver images deteriorate. He discussed how faded, dirty or blurry black and white negatives could be restored and even enhanced through duplication techniques. In addition, he explained how various chemical solutions could be helpful in restoring discolored photographic prints.

Jim Reilly, Image Permanence Institute (IPI), said we have to come to grips with the fact that the silver image, such as we use in preservation microfilming or photographic applications "is not chemically stable enough to resist the contaminants that it might encounter in the real world." Consequently, if we want silver images to be stable over a long period of time we need to "alter the silver image itself...[to] make silver more chemically robust..." That summarizes IPI's silver image stability research, he said.

The research that IPI has done, with support from the Getty Conservation Institute and the Com-

mission on Preservation and Access, has utilized Don Sebera's isoperm analysis model to show how plastic film bases deteriorate at different rates, depending upon temperature and humidity levels. Consistent across all kinds of plastic film bases, Reilly said, is that the rate of deterioration, corresponding to the level of acidity that is building up in the plastic, builds up very slowly at first, and then, when a certain critical level is reached, it zooms upward at an extremely rapid pace.

FACING THE FUTURE WITH COMMUNICATION AND COLLABORATION

After having reviewed where preservation research is today, the participants, prominent figures in the preservation arena, discussed where we need to take it tomorrow. They recognized that there is still much work that needs to be done to establish a coherent national or international preservation research agenda. They wanted to encourage continuing, active, inter-institutional collaboration. They wanted to move from a simplistic collection of disparate projects, to the creation of shared preservation research goals. This planning activity, in the words of Carolyn Morrow, Harvard University, should provide a "creative process of collaboration and peer review and consensus building." The Round Table participants agreed that they did not want to create a body that was too highly organized and managed, or too intrusive. This would stifle the creativity that is central to dynamic research programs. Ultimately, there may emerge, Druzik suggested, a "unified scientific program matrix of interconnected projects driven by a collaborative consortium of institutions."

In the immediate future, more communication and collaboration are essential. Transfer of information is a "very complex, quite often tantalizingly slow process," said Ellen McCrady, Abbey Publications, Inc. The ways "to bridge the gap between the intense knowledge of the technologists and the intense commitment of the preservation managers," said Conway, "are in the room..."

There was consensus that scientists and those organizations sponsoring scientific research bear a responsibility for educating policy makers about the value of science, and for a better diffusion of knowledge among those who need it.

Furthermore, to be truly effective, dissemination of knowledge must consist of more than simply distributing report findings. Mailing a report does not constitute communication, said Druzik. Based upon a recent study showing that most technical information absorbed by policy makers comes through people, and not reports, Druzik suggested conducting a series of highly focussed workshops. These face-to-face forums are necessary to deliver the messages of the scientific community clearly and uniformly, to increase the library and archives preservation community's knowledge, and to influence preservation policy.

Collaboration, it was agreed, is critical to the continuing evolution of preservation science. Normally, the scientific community expects replication of experiments, and encourages variation in opinions. But effective scientific study modes may have to be put aside when resources are tight, as in preservation research, where "sharing of expertise, agreement of test methods and their interpretation, and exchange of results have become necessary," said Hendriks.

"Science resources need to be pooled and shared," said Hendriks, "and used for the public good that these [research] institutions represent." In addition, because of limited resources "it is clear that archives and libraries can no longer afford to pursue separate paths in their preservation efforts," said Hendriks.

The September 1992 Round Table provided an important opportunity for laboratory scientists, technical experts, and preservation administrators to begin discussing areas of common interest and concern. Participants were frequently self-critical, views were often juxtaposed. But the conversations and controversies provided a common ground to begin working together. With each research report given, with each question raised, responded to and remarked about, the challenges and complexity of the field became more apparent. This report represents a summary of the oral proceedings. What follows are the full-length, written presentations prepared by participants.

ENDNOTE

[1]This is an example of "digital technology...redefining what preservation means," as Charles Dollar, National Archives, emphasized it would.

Linda Nainis is the Director of Protext, Inc. a company that assists in protecting and preserving library collection. Before forming Protext, she headed the collection management division at the Georgetown University Law Library. Linda assisted in planning and coordinating the Round Table on Preservation Research and Development.

WELCOMING ADDRESS: PRESERVATION SCIENCE AND A COMMITMENT TO THE FUTURE

WINSTON TABB, *LIBRARY OF CONGRESS*

I am very pleased to welcome all the participants to this Round Table, people from other countries, from other libraries and from our library.

As Chandru said, I did suggest the idea of this conference. It follows on, as I think many of you know, the very interesting meeting we had at the University of Chicago at the end of May that was co-sponsored by the University of Chicago and the Association of Research Libraries. One of the things that we did there was to think about all the preservation problems that exist, the barriers, the challenges that we face in the area of preservation, which is a good place to begin.

But as we ended that conference, I thought, "We've got to do some things, as well." And I thought one of the things we could do at the Library of Congress was to convene a meeting of this sort which brings together people who are doing research, who are interested in research, and to try to develop our own agenda, because I am very concerned about how we spend the money that we have at the Library of Congress for preservation. I thought meeting might be helpful, as well, for others who are making some of those same decisions. So that is what brings us here today and I am very pleased that what I had envisioned as being a round table discussion, four or five or six or ten people — has turned out to be such an important conference with representation, beyond what we had initially envisioned.

In these opening moments of this Round Table, I would like you to use your imaginations and move back in time with me. You are to imagine that you are Charles Fenerty of Halifax, Nova Scotia, and that it's the 1840s. Until now, most paper that you've been using has been made from rags, although some were experimenting with straw and other substitutes. But you have just invented a revolutionary new process for making paper using material that is readily available throughout the world, wood.

You get a very high yield from this raw material by simply mechanically grinding up trees. You allow all the noncellulose material to remain, mixed with the cellulose fiber, so your method is very efficient.

You are elated because you correctly predict this new type of paper will dramatically increase the availability of paper for the production of books, newspapers and other printed publications.

Your invention will make these cultural materials available to the masses, and not just to the wealthy and privileged.

Now let us fast-forward to the present. And, of course, we now know what Charles Fenerty could not possibly have foreseen. That is that in his zeal to create a way to produce paper inexpensively, he left a legacy that we are continuing to deal with: acidic papers.

Charles Fenerty and his successors helped light a slow fire of deterioration that we are struggling to put out. Armed with our scientific knowledge and new technologies, fired by our imaginations and now with some strong support from Congress, we hope ultimately to be able to contain this brittle paper problem. Our experience with impermanent papers has made us painfully aware of the importance of recognizing similar problems that may be occurring with the newer media we're all dealing with.

These newer media require that we not only understand what is going on within the storage medium itself, but also with the specialized hardware and software that are necessary for us to access those media.

Our very presence here is helping us define a new domain, a new area of competence in the field that we should call preservation science. Conservation science pertaining to individual item treatment is further along, but preservation science is still a young field, one in which we are still grappling with the larger issues of whole collections, the issues that ultimately have the power to make an immense difference in our large libraries.

Preservation science integrates research specialties across old and new technologies and, consequently, its vocabulary has a remarkable width. Many of the terms used by preservation scientists hardly existed years ago, like magneto optical storage disks

or even CD-ROMs. Other terms have been around for a long time. So our vocabulary is a mix of old words and new concepts from the guillotine to the gigabyte, parchment to polycarbonates, binding to binary, board to byte, daguerreotype to digital audio tape.

The full development of preservation science as a new discipline requires further organization support, resources and a network of communication. With a system of peer review, a body of literature, published journals in the field and conferences like this to promote communication among researchers, preservation science can truly flourish.

We are all working toward ways to retain the ideas and images that have been produced by authors in all fields of intellectual endeavor and in a variety of media. We are all in search of permanence, usability, access, stability, and quality of image. We all love immediacy and we're hungry for the newest ideas. Furthermore, we recognize that it takes an enormous accumulation of ideas and information to give direction to the future. That is why the high-density storage techniques that have been developed are so important.

But we also must find ways to hold onto our accumulated records and to guarantee access to them now and in the future because functioning rationally and making progress into the future depends on our ability to use our long-term cultural memory.

The Library of Congress is looking to the future and plans to play an important role in stimulating further preservation research. The Library's research and testing laboratory has been providing technical support for the Library's preservation programs, has developed innovative procedures and processes and has sought solutions to problems of permanence, durability and long-term preservation for more than 20 years. The Library has developed new methods of preservation to match its diverse collections and you will hear more about these methods during the next two days.

In some areas of preservation, the Library can serve its own interests while, at the same time, assisting others who are part of the preservation team across the nation and the world. It will take all of the best minds and all of the best research centers to solve the challenges of preserving our wide range of media. We have to work together to form an ever more integrated universe of preservation scientists and preservation administrators who will unite behind the common goal of preserving our intellectual heritage.

All of us at the Library of Congress have high expectations for this meeting. We hope it will illuminate new areas of research and will better inform us about recent breakthroughs that can affect our work in several important areas of preservation science.

In addition, I anticipate that publicity about this conference will help raise general awareness of how the research and testing going on in preservation science needs and merits the support of decision-makers, policy makers—ultimately those on whom we depend for support of our research centers and preservation efforts.

How we progress towards this goal is up to the people who are in this room and to our colleagues. We look forward to working with you. We want to publish the paper, and we hope that all of you will end up thinking, when you leave tomorrow, this was a good place to have been. And we must also think about what we're actually going to do, once we've decided what needs to be done. Thank you very much for coming today.

Winston Tabb is the Associate Librarian for Collections Services, Library of Congress. A magna cum laude graduate of Oklahoma Baptist University, he earned a master's degree in American literature from Harvard University in 1964. After Army service in Southeast Asia, he earned a master's degree in library science from Simmons College in 1972. He represents the Librarian on the National Commission on Libraries and Information Science, the advisory committee to the White House Conference on Libraries and Information Services, and the Association of Research Libraries. He has served as the Library's liaison to the Research Libraries Group (RLG) Shared Resources Committee and as secretary to the IFLA Section on Interlending.

KEYNOTE ADDRESS: THE MYOPIA OF PRESERVATION RESEARCH

PAUL WHITMORE, CARNEGIE MELLON UNIVERSITY

As another campaign season reaches its frenzied peak, and governments at all levels hold their collective breath as they await the news of their employment status, I give thanks that conservation jobs are not elected positions. If they were, a large number of us might have difficulty selling our accomplishments at each election. In what other field is maintenance of the status quo an ideal which can only be aspired to? We measure success by how much things have deteriorated, and our motto would be an uninspiring, "Well, things could have been much worse!" We may soon be seeing how well such a message is received by the electorate.

Although it might be an arduous battle, I believe most of us would be able to justify our profession. Society has already made the judgement that art objects, libraries, archives, and cultural monuments are worth treasuring for many reasons. Conservators seem to take for granted this approval from the public, and except for the occasional fund-raising efforts, there has been relatively little concern with educating the public about our profession. Much like any other specialized discipline, we tend to talk more to one another, and our failure to educate others only hits home when "outsiders" level criticisms that are viewed by "insiders" as well-meaning but ill-informed.

As confident as I am that the conservators, archivists, and librarians would be able to survive an election, I am much less certain that the scientists in our profession would have a smooth ride to re-election. In our society at large there are ominous rumblings about the fundamental value of scientific research, especially as it is practiced in academia, and the relative priority which should be placed upon science vs. other social investments, or upon basic science vs. applied sciences. While the arguments could perhaps ultimately evolve to questions of faith—is basic research (or any individual project) really worth the investment? does science cure society's ills or add to them?—the discussion is unproductive if the scientific enterprise is poorly understood. As this debate plays out, we shall be seeing efforts on the part of the scientific community to educate the "outsiders" on just what it is they really have been doing, and on the value of science to society.

I would like to believe that the conservation profession is more attuned to the process of and value of conservation research. To be honest, however, I must admit to myself that I actually only get feedback from colleagues who will speak to me in the first place, and as any pollster would tell you, you don't get your random sampling at the convention. The recent surveys which have circulated in some of the specialty groups at the American Institute for Conservation have produced some especially disturbing opinions which may or may not be carefully considered. Since I view my job as ultimately one of communication to conservation professionals who might benefit from our work, I feel it is incumbent on me, as it is on every scientist here, to be able to explain clearly and concisely why I value my research activity so much that I am willing to devote my career to it.

This paper is not going to be that lucid explanation. I have not yet arrived at that gripping epic, rich with visual imagery, that captures the essence of what we do, if not the thrills and anguish of it. What I have to share is merely a preliminary sketch, another stage in the evolution of ideas that attempt to describe some of what research is all about.

In this paper I will examine conservation research by probing at its limits. What conservation questions are answered well through scientific study, and which questions are unlikely to provide definitive, unambiguous results? Of what value are the tentative results, and who should be the judge of their value? Given that treatment decisions may be made with only incomplete scientific information, are there prudent measures that should be taken as precautions against the inevitable missteps?

FRAMING THE QUESTIONS

Recent efforts have been made in conservation to try to take best advantage of what are now recognized as very limited scientific resources. One of those methods has been the attempt to produce a list of "research priorities" which have been selected by a group of specialists as the most critical or important problems that require some sort of scientific "data." Entries on such lists are usually in the form of perceived problems whose origin and solution have not been identified. It is generally assumed that the selection of these problems will encourage the undertaking of the research required to arrive at the ultimate goal: how do we cure these ills?

As important as this activity is in helping researchers make their efforts useful, anyone who has done research will testify that the prospects for success depend on the question one initially asks. It is my belief that a "research area" which has only a general problem-oriented direction is poorly focussed, and the expectation that research will produce a bottom-line result is unrealistic. The reason for this is that a seemingly straightforward question such as "how do I safely bleach discolored paper?" is in fact proposing a number of related questions: What is the cause of the discoloration? What treatments will effectively bleach the discoloration? Are there harmful side-effects in the short-term, or in the long-term?

The case can be made that all of these questions should have answers before embarking on any treatment strategy. And yet, these are fundamentally different questions, some of which can be answered more easily than others. The setting of research priorities needs to address problems at this level, for considerable resources can be devoted to answering the more difficult questions. What do conservators really need to know, and when do they need to know it?

ANSWERING THE QUESTIONS

In judging the priority to be placed on specific research questions, it is important to be cognizant of the difficulty of the questions raised, for that will be the guide to how long one must wait for the results of the research. Although each research problem, and each approach to studying that problem will clearly have unique features that may make the project easier or harder — for instance the availability or lack of a critical instrument — there are some general criteria that can be used to estimate the difficulty of the research defined by the question being posed.

My suggestion for making this assessment is to consider conservation research as being an inherently myopic activity, in the sense of being nearsighted (rather than the alternative pejorative sense of being shortsighted). It is difficult for those who enjoy perfect vision to truly appreciate the shadow world viewed through the uncorrected vision of those of us who suffer severe myopia. If you can imagine in your mind's nearsighted eye, distant objects cannot be brought into focus; only the outlines or major features can be discerned at a distance; and details can only be distinguished when the objects are brought extremely close. Conservation research is afflicted with this limitation, only it is the object distant in time rather than in space that is difficult to resolve in any detail.

Which are the straightforward research questions? Like any myopic person can attest, the easiest object to see is the near one having few details. That is, a question of measuring a big effect over the short term will be the easiest to probe. How do I extinguish a fire in my library? The efficacy of a fire extinguisher and the immediate side-effects of its use on the condition of the surviving books are relatively easy evaluations to make: the criteria are simple and easily measured and compared. Questions about the simple and short-term are the most easily answered.

Adding complexity to the system under study naturally makes the research more difficult, but it is not just the addition of detail which makes for difficult viewing. I can examine the engine of my car and discern the various wires and hoses with little difficulty, but it is the interconnection of the details, and ultimately the underlying cause of that annoying little engine noise, that is difficult to trace. It is this paradox upon which much of scientific research is built: in order to understand the subtle details, one must investigate so closely that the overall perspective, the causal connections, may be lost. Researchers thus seek to approach identical systems from different directions, hoping that by examining the details from enough perspectives one can reconstruct the entire complex system like a mosaic.

Certainly the most difficult questions for the myopic conservation researcher are those asked of the most distant objects: the nature of objects as they will evolve over the coming centuries. Almost all of the most perplexing questions about the longevity of (relatively stable) contemporary art and library materials, or about the long-term side-effects of a conservation treatment or preservation measure, seek to know the details of the most indistinct of images. The farther into the future one seeks to know about, the more difficult it becomes to bring details into focus.

However, research into such long-term changes is not as simple as peering at a distant object with a powerful telescope, for the objects we seek to understand are often those which the world has not yet seen. One can make reasonable predictions of the future of materials such as oil paintings or cotton fabrics, because we have observed very old examples of them. However, no one can describe with certainty centuries-old acrylic paints, plastic artifacts, or peroxide-bleached paper, because such aged objects do not yet exist. Short of consulting a psychic, how can one learn what the future holds in store?

The short answer is, one cannot know the

12

future, at least not to any level of detail. In light of this sobering prospect, the best we can hope for is to make educated guesses about the future, to seek at least the general features of these distant objects. This is what researchers are really doing in trying to explore the long-term changes in materials, and since direct observation of the future is not possible, heavy reliance must be placed on oblique approaches to the problem. The chemistry of materials is studied in great detail to try to understand the aging that an object might be prone to under the influence of various intrinsic or extrinsic factors. Tests are designed to accelerate these aging processes to explore what changes might occur in the advanced stages of these specific deteriorations.

This investigation based on such so-called accelerated aging tests is the most used and abused research method in conservation. Although accelerated aging tests are widely used in the development of durable materials, such tests are generally viewed with some skepticism even when the results of the tests can be compared with naturally aged materials. The aging process, especially the slow deterioration of relatively stable materials, is often not a single process but a combination of several interrelated processes. It is improbable that the exact combination of degradative mechanisms can ever be duplicated in any accelerated aging test, and one hopes to at least produce the effects of the most important deterioration route.

In conservation research there often is the added difficulty in having no naturally aged materials with which to compare. As a result, different researchers may adopt different test methods in trying to glimpse the same distant future. There is a saying that if you don't know where you're going, any road will get you there. In this case, different tests will probably produce materials that appear to have aged, but arguments about which is more closely related to natural aging are rendered moot.

It should come as no surprise that research into the long-term changes in objects should produce results that fall short of the definitive answers conservators seek. Conclusions born of such research must be regarded as tentative, for they are interpretations of distant images viewed, often from completely different vantages, by the nearsighted. Expert opinions about the outcome of a single research study can be diverse, and consensus may only be achieved after a number of studies have allowed assembly into a coherent image. And yet, because of the limitations of the studies themselves, that image could still prove to be wrong.

It is this tentative, subjective nature of these long-term predictions which demand they be communicated and utilized with appropriate prudence. Conclusions of this sort cannot be separated from the limitations of the experiments or of the judgements of the researchers. It may be tempting and expedient to hold up any conclusion as uncontested fact, but even consensus opinions are still just opinions. To lose sight of the provisional nature of these predictions is to invite embarrassment, irritation, or disillusion when the consensus opinions inevitably change.

USING THE ANSWERS

Conservation research thus encompasses a broad spectrum of inquiries, ranging from the straightforward to the speculative. Ideally, one might desire the conclusions to all of these research studies before embarking on a course of action, but clearly that is unrealistic given the resources available. It is reasonable to ask, then, what research answers are necessary before a decision can be made? Of what value are the sketchy predictions of the long-term consequences of conservation decisions? Can anything be done to position ourselves to recognize or remedy conservation decisions that prove to have been wrong?

To address the first of these issues, the judgement of how much technical information must be available before making a decision is ultimately a subjective one. Conservators, being the policy makers or risk managers, must weigh many other considerations besides the technical ones, and here too the experts may have difficulty in reaching a consensus on the appropriate action to be taken.

Despite the sometimes daunting complexity of the technical side of many conservation decisions, conservators often use some general guidelines in reaching these decisions. The first question is usually, is this object at risk, and how urgent is the problem? Put another way, how long can one wait before making a treatment decision? The answer to this question, which may necessitate research efforts in itself, will set natural limits on the knowledge one can expect to have before decisions are made. Burning books require attention immediately, and the possible side-effects of treatment are not governing factors in a policy decision. Less urgent problems may allow more time for research to provide information. This judgement of how long one can put off decisions is vital, and research which can be used to make that judgement should have a high priority.

Similarly, one could rank in priority the research into a particular problem on the basis of the time scale of the changes to be studied. High priority would be given to answering questions of immediate effects: is a treatment effective, and are there immediate side-effects of the treatment? Questions of the short- or long-term effects might be given subsidiary importance, especially if the research will not be completed before the ultimate decision must be made. Only if the object is not at immediate risk and the problem is not an acute threat, then there may be the opportunity to explore those questions of the long-term consequences of a treatment.

Given that decisions will always be made in the absence of all the desired information, there is a high probability that choices made reasonably in light of the available information will have undesirable consequences. To be fair, it will always be easier to identify the bad treatments than the good ones, which often attract no notice. Is there anything we should be doing to prepare ourselves to recognize or remedy materials or conservation methods gone sour?

There are four steps that can help, and in particular should be considered as integral parts of all, especially relatively untested, treatments. Some of these are already part of routine conservation practice, but others should find wider application than they do. The first of these safeguards is documentation of the history of an object. This might be considered to include records of not only the conservation treatments themselves but also of an object's manufacture, storage and display environments, and its handling and travel history.

The other three precautionary steps that should be considered involve studies of objects as they naturally age. These studies become ongoing tests of the validity of our original predictions. Ideally one would have a non-invasive condition monitor such as a color measurement which would indicate the stability or the aging of materials which are modern or which have been repaired, so that we would learn about the natural aging process as it occurs. Lacking this condition monitor one should consider periodic analyses of these objects to obtain the same information. Such testing is done rarely, but when it has been, such as in current studies of synthetic picture varnishes applied several decades ago, the insight into both the materials and into our testing methods has been profound. Only with the routine monitoring of objects whose future is cloudy will we be prepared when the unanticipated aging behavior emerges.

If regular monitoring should become routine, the results of the monitoring tests must be disseminated, especially when the unforeseen occurs. This can include changes which were either better or worse than were expected, for both may provide clues as to how to improve the predictions next time. Finally, the observation of the unexpected demands critical study: were our predictions or expectations really incorrect, or did this particular object experience peculiar conditions which altered its expected aging? Should we expect other related objects to be similarly affected?

Clearly, implementing such a plan necessitates the devotion of significant research resources. The basic aging processes must be understood, and sensitive analytical methods to detect these changes must be developed. Equipment and time to perform such testing on a routine basis will be considerable. As experience has already taught us, archives of materials whose history is well-documented are invaluable resources in the development of these tools, and efforts to assemble these archives should be encouraged. With the additional insight provided from studying natural aging, conservation treatments and accelerated tests must be evaluated and refined.

CONCLUSION

I do not expect that such an approach can be implemented anytime soon. Yet I hope that this consideration of the prospects for reliable research conclusions, and not just the focus upon materials or techniques of interest, will also be used in determining the most efficient allocation of our precious research resources.

We live in a technologically well-endowed society, and our capacity to improve the prospects for a long life for our treasures is awesome. Equally great, though, is our potential for unwittingly wreaking massive harm. As has every generation of custodians before us, we seek to do our best to safeguard our treasures. We do our best, but our myopia allows us only blurred vision into the distant future. Continued vigilance over the objects in our care is an important precaution: we cannot consider that our responsibilities ended once the conservation decisions were made. Only by continuing to view those distant objects as they draw near will we be prepared to deal with the consequences of our well-meaning but fallible judgements.

Paul Whitmore earned a B.S. in Chemistry from California Institute of Technology, and a Ph.D. in Physical Chemistry from the University of California, Berkeley. From 1984 to 1986 he studied air pollutant damage to art materials at Environmental Quality Laboratory, Caltech, Pasadena, California. From 1986 to 1988 he was Assistant Conservation Scientist, Center for Conservation and Technical Studies, Harvard University Art Museums, Cambridge, Massachusetts. From 1988 to the present his title has been Director, Research Center on the Materials of the Artist and Conservator, Carnegie Mellon University, Pittsburgh, Pennsylvania. His field of specialization is conservation science research on modern art and archival materials.

SESSION I

INTRODUCTIONS

PRESERVATION AND THE ECONOMIC INVESTMENT MODEL

SCOTT BENNETT, *JOHNS HOPKINS UNIVERSITY*

ABSTRACT

The library community urgently needs research on an economic investment model to guide the design of comprehensive and effective preservation programs.

I am Scott Bennett, the director of the Milton S. Eisenhower Library at Johns Hopkins University. As a researcher, I am a student of literature and a social historian. As a manager of library materials and university funds, I have long been concerned about preservation.

I am keenly aware of my debt to modern researchers—starting almost forty years ago with W. J. Barrow—who have lead us to understand why paper and other information media are not stable and what can be done to preserve the record of human experience those media carry. One of the pleasures of attending this Roundtable is to acknowledge the critically important research supported by—among others—the Getty Conservation Institute, the Image Permanence Institute, the Library of Congress and national libraries elsewhere abroad, the National Archives, the Commission on Preservation and Access, and the National Endowment for the Humanities.

As a library manager, I have been particularly concerned with mass preservation treatments. At Northwestern University I oversaw the design and construction of a new environmental system for a major library building. While at Northwestern and since coming to Johns Hopkins, I have worked to move libraries to adopt mass deacidification. The Eisenhower Library has taken special care to analyze, assess, and document its early experiences with mass deacidification.[1]

The purpose of this Roundtable is to review where preservation research is today and where we need to take it tomorrow. I will not comment on the research that builds our understanding of <u>why</u> preservation treatment is needed or <u>what</u> treatments are technically effective. I wish instead to register the urgent need for research on <u>how</u> those treatments might be employed. And in posing the question of how to treat collections, I mean to identify the need, not for technical research, but for economic analysis and modelling.

At heart, preservation is an investment activity. But there is no library director today—myself included—who can adequately explain or justify her or his library's preservation program as an economically efficient program of investment. We are doing things "that work;" we are doing things that other libraries do. Some of us may hope, but we certainly do not know, that our activities will be adequate to the challenge before us. Speaking for myself, the programs of intellectual triage that have been the most visible activity in what we call our national preservation program seem to belie the very word preservation and to abandon future generations of researchers.[2]

I make this harsh statement because I think it true and to emphasize the urgent need for an economic or investment model that might guide our preservation programs. Such a model would have two major components. It would, first, refine existing estimates of the size and nature of the preservation problem we face. In doing this, the model must conscientiously assess from the researcher's point of view what part of the existing verbal record must be preserved. To start elsewhere, and especially to start (as some have) with the assertion that libraries will save only 20-30% of a literature because that is all we can afford to save, is to ensure at the outset the failure of our preservation activities.

Second, having described the task to be completed, the model needs to show the library community how best to invest its limited preservation resources. Some key inter-related issues to be considered in this economic model are the different levels of anticipated use for various materials, the storage costs of different recording media, the comparative cost and effectiveness of the full range of preservation treatments, media and format obsolescence rates, reader preferences for various media and formats, and the effectiveness over time of various preventive and maintenance treatments. It is particularly important that the investment model consider time not as an enemy to be defeated once and for all, one book at a time, but as a powerful factor in shaping treatment strategies for entire collections and for maximizing over time the effectiveness of each preservation investment decision.

The objective of the economic modelling research I propose is to build comprehensive and

coherent preservation programs that respond adequately to the challenges we face. That is the only way we can free library readers from a future that is likely to be impoverished by the loss of important parts of the record of human experience.

REFERENCES

1. Regina Sinclair, Head of the Preservation Department at the Eisenhower Library, and I will publish later this fall a report of our first year's experience with mass deacidification. The Eisenhower Library is the first library to have this much experience with mass deacidification as an ordinary production activity.

2. See Scott Bennett, "Buying Time: An Alternative for the Preservation of Library Material," *ACLS Newsletter*, 3 (Summer, 1991), 10-11; and "Strategies for Increasing [Preservation] Productivity," *Minutes of the [119th] Meeting [of the Association of research Libraries]* (Washington, DC, 1992), pp. 39-40.

Scott Bennett is director of the Milton S. Eisenhower Library of the Johns Hopkins University. His research interests include nineteenth-century publishing history and bibliography. He has a long-standing interest in preservation administration.

CONSERVATION POLICY IN THE NETHERLANDS

GERRIT DE BRUIN AND TED STEEMERS, *RIJKARCHIEFDIENST, THE HAGUE, NETHERLANDS*

In 1990 the Minister of Welfare, Health and Cultural Affairs started a national program, the Deltaplan, for the rescue of our national Cultural Heritage. Since then the possibilities for a new start in passive conservation and scientific research in the conservation field have grown.

In support Minister drs. H. d'Ancona commented that: "The preservation of the past is more than a gesture of respect for our ancestors. It is also our very real duty to protect the ideas and traditions embodied in works of art, books, documents, implements, historic buildings, etc. and to keep them alive so that they can inspire generations after us with new ideas and expressions of culture. To me, this is the greatest value of the Deltaplan for the Preservation of Cultural Heritage. I am sure that this approach will vary from one country to another. I am equally sure that intensive international cooperation in a number of areas will be both possible and necessary for example, the area of scientific research into the causes of decay and possible methods for conservation and preservation. We have a common interest in the preservation of our collective cultural heritage, for now and for later."

Although the research on air-pollution in relation to the degradation of paper (ACBAM) started in 1986, also initiated by the Ministry, it became international in 1991, thanks to the recognition by the European Community, with Sweden and France as partners. The Deltaplan initiative of the Ministry made it possible to start working on a real and, what's more important, a realistic general conservation policy. To begin, the General State Archives (ARA) and the Royal Library (KB) started a cooperative partnership named The National Preservation Office (CNC). The CNC took the responsibility for the pilot year of a mass preservation project.

It started with a damage survey, based on the Stanford method, with the help of Donald Sebera from the Library of Congress and Jonas Palm from The University Library of Uppsala. Taking as the starting point the aims, definitions and the method used for the damage survey, the following picture emerges for the General State Archives and the Royal Library. For the period under review (1800-1990), at the ARA 1.5% brittle paper was found and 6.3% of the paper was in a 'weak' category. Calculated on the basis of individual years, the boundary years could be set with greater precision at 1840-1950. Within this period 2.9% of paper was found to be brittle and 8.8% to be weak. The survey results showed that paper dating from 1870 to 1880 was in the worst state of deterioration: 7% brittle and 20% weak. For the period under study (1800-1990), at the KB there was 2.2% brittle paper found and 4.4% fell into the 'weak' category. On the basis of individual years, the boundary years could be set with greater precision at 1840-1950. In this period 8.0% brittle paper and 14.8% weak paper was found. The survey results showed that paper dating from 1880-1890 was in the worst state of deterioration: 21% brittle and 16% weak. The sub-collections of the KB are divided as follows: monographs, brittle 2.7%, weak 12% (1840-1950); newspapers, brittle 24.3%, weak 18.7% (1840-1950); periodicals, brittle 2.6%, weak 14.7% (1860-1930). No brittle paper was found in the Depot collection.

In determining short-term conservation requirements (within 10 years), the brittle and weak categories were combined (endangered material). Regarding the ARA, this means that 7.8% of the 63 km of the classified collection which represents the 1800-1900 period should be subject to conservation measures, i.e. more than 4900 meters. As far as the KB is concerned, the same period gives 6.6% of the 1.5 million volumes that should be treated (endangered material). Selection to the level of the individual item (single document/volume) would be too labour intensive within the framework of mass conservation. Since selection of individual items is not possible, this means that the amount of material which should undergo conservation, determined by selection on the basis of decades, would work out to be 42% of the collection, or 26.5 kilometers. At the KB such an estimate works out to be about a third of the total collection, or 500,000 bindings. This data comes from: *Bedreigd papierbezit in beeld / Endangered books and documents.* CNC-Publikaties, no. 2. Den Haag, 1991.

Part of the pilot year mass conservation project was a desk-study of seven methods for mass conservation. Besides an inventory of mass conservation methods, the prime aim of this desk study was to examine whether any of these methods could be of interest to our institutions. Aspects of safety, location, capacity

and costs were studied. This data was published in the report: *Methoden voor massaconservering, Analyse and Evaluatie*. CNC-Publikaties, no.1, Den Haag, 1991.

Another part of the pilot year mass conservation program (CNC) is to study the developments and results of three firms (pilots) in the Netherlands which have their own mass conservation system. The technical support is the resposibility of the Netherlands Organization for Applied Scientific Research. The following issues will be studied: good penetration and distribution of the deacidification solution, safety, environmental consequences, costs and shape/material of the objects.

In December 1991 a meeting entitled: "Conservation of Acid Paper Materials and the Use of Permanent Paper" was held in the Hague, organized by the Commission of the European Communities (EC) and the National Preservation Office (CNC). Twelve countries of the European Communities sent experts on preservation and conservation. Recommendations were made in a report entitled: *Expert meeting on conservation of acid paper material and the use of permanent paper*. CNC Publikaties, no.3, Den Haag,1992.

A preliminary literature study of the Chemiewinkel (information bureau on chemicals) from the University of Amsterdam was completed in cooperation with the trade group on crystallography and the trade group on organic chemistry. A FTIR project at the TNO Research Institute showed that the FTIR spectrum can be used in the study of deterioration of paper on morphological differences in crystallinity. The research focused on the formation and location of crystals after deacidification treatments, and their influence on ageing properties of paper. The research was discussed in a report by R. Williams entitled: *The investigation of the potential disadvantage effects of paperdeacification / alkaline reserve on long term*. The Ministry of Welfare, Health and Cultural Affairs, Amsterdam, 1990.

The Technical University of Enschede carried out a preliminary study in collaboration with The Central Research Laboratory into methods for reinforcement of brittle paper with monomers followed by radiation to accomplish polymerization. A literature survey has been finished and research will be continued on the possibilities of the use of organic compounds for strengthening brittle paper. The results of this research were published in: *Methoden ter verbetering van de mechanische eigenschappen van gedegradeerd papier*. Universiteit Twente in collaboration with the Central Research Laboratory, Amsterdam, 1991.

In 1991 a pilot air filtering project started in the General State Archives in the Hague within the framework of the Deltaplan with assistance from the Ministry of Welfare, Health and Cultural Affairs. The aim of the pilot was: to investigate the architectural (im)possibilities of filtering air in an existing building, the effects of air filtering and the (energy)costs. Seven different types of filters were installed. The north air conditioning unit has one big filter to clean the incoming air. Into the south air conditioning unit six different types of filters were installed in six different depots. On-Guard monitors were used to collect data.

The Central Research Laboratory carried out a test to investigate the damage on historical documents after duplication. Fourteen copying machines from six different firms are tested. The doses are related to an UV-amount of 50 lux during one hour of light exposure. The aim of this test was to find out how many times a copy can be made to reach the total amount of 50 lux. Also was tested the influence of electronic flashes used by photographic cameras on historical materials and buildings. Findings reported by J.G. Neevel in: *Ultraviolet-afgifte van fotokopieerapparatuur en elektronenflitsers'*. CL Publikatie, Amsterdam,1991.

TNO Research Institute has completed a study for the General State Archives to investigate the influence of mobile shelving systems on traditional climate control.

Other pending conservation projects are as follows:

- The Central Research Laboratory of Art and Science in Amsterdam will coordinate scientific research in the Netherlands. The study of deterioration factors on archival, library and museum objects will be done in small working groups.

- Permanent paper and standard specifications for archival materials (acidfree wrapping paper and boxes) in the Netherlands will be completed by the Central Research Laboratory in Amsterdam.

- A study on the effects of buffered boxes on the contents (documents) compared with the effects of unbuffered boxes on air pollution will be initiated.

• A Damage Assessment Manual for pre-1800 archival materials in the Netherlands will be published by the State Archives.

• A disaster plan will be created for museums, archives and libraries.

• Investigation of penetration of insects into depots of a relatively new archive building will be investigated by the General State Archives under the supervision of Mr. Bert van Zanen.

• The invention of an easy to use test kit for fungi viability in archive material.

• The design of a computer program for teaching the proper handling of archival objects.

• The design of a restoration laboratory by an industrial designer; a study programme in cooperation with the Technical University Delft.

• Investigation into the discoloration of mounted graphics in the municipal archive of Amsterdam.

Gerrit de Bruin has worked at The General State Archive, Den Haag, since 1978. He is currently the Preservation Officer and Board of Directors State Archivist (since 1989), and previously held positions as Head of Conservation, General State Archive (since 1982), and Archive Restorer (since 1987). He earned a Higher Diploma, Paper and Book Restoration from Opleiding Restauratoren (State Training School for Restorers), Amsterdam. He is a teacher at The State School of Archivists in Den Haag, and is a member of several research working groups.

Ted Steemers is currently Preservation Officer for the board of directors, State Archives in Maastrychd (since 1989). He previously worked as archive restorer at the State Archives in Maastrychd, Netherlands (since 1976). His higher diploma is in paper and book restoration at the Opleiding Restauratoren (State Training School for Restorers), Amsterdam. He now teaches at the State Training School. He is Chairman of the Dutch Association of Book Restorers, and a member of several research working groups.

PRESERVATION RESEARCH NEEDS AT THE NATIONAL LIBRARY OF MEDICINE

MARGARET M. BYRNES, *NATIONAL LIBRARY OF MEDICINE*

ABSTRACT

The author outlines the National Library of Medicine's specific interest in research on preservation of audiovisuals, electronic formats, and coated paper. Other areas of needed research are briefly mentioned.

The National Library of Medicine is the world's largest research library in a single scientific and professional field. The National Library of Medicine Act of 1956 mandates the Library to "acquire and preserve books, periodicals, prints, films, recordings and other library materials pertinent to medicine".[1] To date, our preservation program has focused on four main areas of activity: microfilming all brittle monographs and serials in core medical subjects, library binding, conservation of rare and valuable materials, and working with publishers and paper manufacturers to eliminate the use of acidic paper in biomedical literature. Much of our energy in the first six years since the Preservation Section was established has gone into the brittle book microfilming program. Since 1986, we have filmed approximately 45,000 volumes. Now that the Library's microfilming program is well under way, we are beginning to turn our attention to the nonprint collection.

At the end of 1991, NLM's general collection contained approximately 22,000 audiovisuals and other non-paper formats, including videocassettes, audiocassettes, slides, recordings, filmstrips, interactive videodisks and CD-ROMS. This collection is especially important in biomedicine for several reasons. Audiovisual formats can document current medical techniques or innovative procedures in ways that print formats cannot. To the student or health professional, a visual presentation of a particular surgical technique can be far more instructive than the most well written text. Slides can show unusual medical conditions that may not be as well reproduced - if reproduced at all - in published volumes. Films from the 1940's about prevention of venereal disease or those from the 1950's alerting people to the need for inoculation against polio, for example, can be important resources for today's social or medical historians. Recent videos on the causes of AIDS or interactive videodisks on diagnostic procedures may be equally valuable in future years to those studying the history of public health outreach efforts related to AIDS or techniques used in the early 1990s for educating health professionals to recognize its symptoms.

Since NLM is considered the library of record for biomedicine and since the preservation of audiovisuals presents such a challenge, many biomedical libraries in the U.S. are not attempting to preserve their own nonprint collections. They are depending on NLM to ensure that these important nonprint sources survive. This places a particular burden on us to determine how best to proceed. A few months ago I conducted a review of the literature on preservation of nonprint and electronic resources and was struck by two things: how little new information has come out in recent years and how much contradiction there is in the literature - particularly with respect to the durability and longevity of the various formats and the temperature and humidity conditions under which they should be stored. It was clear that much more definitive work needs to be done in these areas. Of most recent concern, I think, are compact disks, videodisks and magnetic formats.

We have had a modest program of copying to 16mm film the historical motion pictures in our collection. Since this is a very costly activity, it was decided several years ago that we would copy only those films that are in poor condition and create video service copies for the remainder. In some cases, digital masters have been made. We are aware that most videotape is not considered a permanent medium. We are also aware that most of our slides will fade with time and that the audiotapes are fragile. More research and development of affordable and more stable alternatives for these media are much needed. More information on the advisability of digitizing audiovisual materials would be particularly welcome. We need to base our plan for preserving the non-paper collections on more solid data and more reliable recommendations than seem to be available today. We must be able to launch a well thought out and affordable program for preserving NLM's non-paper holdings and we must do so fairly soon.

A related area of concern to us is computer software and electronic publications. For the past several years, we have been receiving an increasing number of publications that are issued on or accompanied by diskettes. Soon enough we expect to see many of the printed sources we now purchase in paper become available only in CD-ROM or some other electronic form. We face an even greater challenge from the impending development of more electronic journals and other forms of biomedical communication that will be accessible only over the national network and not housed in the library at all. With the advent of electronic libraries, we must begin to develop a plan to ensure that such information remains available for future consultation. Despite issues of ownership and copyright and lack of agreement concerning whose responsibility it will be to keep such data accessible, it is likely that as a library of record we will have some preservation responsibility in this area. There are questions concerning the rates of degeneration of electronic signals and the frequency with which the data will need to be refreshed - especially as the chemical composition of the various media, whether tape or disk or some future format, changes over the years. Assuming that we will make the commitment to refresh files and upgrade equipment as new hardware and software are developed, we will want to transfer the data to media that will minimize the chances of information loss and the frequency with which refreshing must be conducted. More research in this area will be needed if we are to invest our resources of time and money wisely.

As for the continuing need for research in paper chemistry, NLM has a number of specific concerns. Since many of our journals and monographs are printed on coated paper, areas of research that would be of value to us include: longevity studies of coated paper; identification of the manufacturing processes and chemistry of the various coatings that have been used over the years; more work on the effectiveness of mass deacidification processes on paper treated with different types of coatings; alternatives to oversewing as a method of library binding for thick coated papers; and development of paper coatings that will not cause pages to stick together permanently when wet. The durability of the newer paper pulps that use less fiber and more filler and the effect of lignin on paper permanence are also of particular interest.

NLM shares with many libraries the need for more research on the effect of gaseous pollutants on all types of materials and the long term effect of using polyvinyl acetate adhesives for library binding and conservation. More testing should be done of the materials and methods used by library binders - particularly in areas where disagreement exists (e.g., the durability of volumes bound flatback with wide hinges). Development work is also needed on a reliable, affordable means of monitoring air quality in storage areas. And finally, we are still very interested in having safe and practical methods for treating collections affected by mold and mildew. NLM would welcome research projects in any or all of these areas.

ENDNOTE

1. National Library of Medicine Act of 1956. 84th Congress. PL 84-941.

Ms. Byrnes has been head of the Preservation Section, National Library of Medicine since 1986. Prior to that she was Preservation Officer, the University of Michigan Library. She is an active member of the Preservation of Library Materials Section, American Library Association and former member of the National Advisory Council to the Commission on Preservation and Access.

PRESERVATION AT YALE UNIVERSITY LIBRARIES

PAUL CONWAY, *YALE UNIVERSITY*

My name is Paul Conway. In June I assumed responsibility as head of the Preservation Department at Yale University Libraries. I came to that position after working for 15 years with archives and manuscripts, mostly with the National Archives and Records Administration. Six years of that time I was intensely involved in research centering on users and use of archives and on preservation program development. I have been particularly interested in understanding who uses archival materials and how archives are used to answer historical questions, largely for purposes of informing patron services and preservation decision-making. My remarks are therefore influenced by the results of that research.

I am here in part to report on the status of a project at Yale University to test the feasibility of converting to digital images materials that exist primarily, and in some cases exclusively on microfilm. Some of you may already be familiar with this project as a result of reports prepared by project director Don Waters and published by the Commission on Preservation and Access. A status report on phase one of the project is about to be released and an abstract of this most recent report is appended to these remarks.

For those of you who are not familiar with Yale's imaging project, I will summarize the concept briefly. The focus of the three-year study is to explore the feasibility of converting microfilm to digital images on a large scale (large as far as past library-based imaging projects have been concerned) and making those images accessible campus-wide and beyond. The goal is to convert 10,000 volumes over a three-year period and evaluate the success of that effort. To assist us in the design process, a Request for Proposals was issued nation-wide and the resulting competitive bids were evaluated by the project team. Based upon this evaluation, Xerox Corporation was chosen as the project's supplier/integrator. In its fundamental design, the hardware and software configuration is quite similar to that utilized by Cornell University in an ongoing project to convert a small group of books to digital images.

By the end of 1992, we expect to complete a formal contract with Xerox and install the equipment in the Sterling Memorial Library on campus. The project has two operation phases. The first phase involves testing and evaluating the integrated system by converting 100 volumes on a single workstation. This phase will enable the project team to complete its training, to identify and define primary workflow issues, to select microfilmed volumes for inclusion in the second phase, and to develop appropriate strategies for addressing the significant issues involved in capturing document structure information. In the second operation phase, two additional workstations will be added to the system configuration to permit the high-speed conversion of the remaining 9,900 volumes and to facilitate remote access to the image database.

On the surface, the central question that needs to be addressed in this project is straightforward; namely, is high volume digital conversion from microfilm feasible, cost-effective, and appropriate for a large academic library? Given the current state of imaging technology as it has been adapted by corporations as well as by state and local government agencies, the question of feasibility may turn out to be a straw man. Technical issues are far less interesting and challenging than some of the other issues that must be evaluated if the project can be deemed a success.

One of these issues has to do with the quality of the input sources: what criteria should be used to judge the input microfilm in order to obtain the best possible digital image data. Another issue of interest is the pros and cons of using a service bureau to carry out conversion activities versus doing the work in-house. Even more important are questions concerning the possible impact of the existence of a large image database on campus. How will it affect the work habits of scholars who choose to use this system, either remotely or in the library?

Other important issues are associated with the usability of digital image technology, including the visual display of image files on a computer screen, the representation of a document's structure to users, and the nature of browsing in an on-line environment. We have put a lot of faith in the power and advantages of random access over the more restrictive linear access represented by microfilm. Serious investigation needs to be undertaken of the assumptions underlying this faith. Yet another issue that could be evaluated is the promise of the integration of digital image sources with other sources of information in other forms (pa-

per, microfilm, audio-visual) and how these newly integrated information sources challenge the traditional work habits and the needs of scholars. Because there will be many years before key scholarly resources are available in digital form, what are the challenges that libraries face in the interim?

Only with serious applied research over time will we be able to come to terms with theses issues. The Yale imaging project, among its other accomplishments, will seek to identify the range of research issues that could be pursued. I believe that in the process of identifying them, we will be giving further definition to the concept of "preservation science" outlined in the opening remarks by Paul Whitmore. Preservation science is clearly something far broader than conservation science. If we seek to define preservation science merely as materials science on a grand scale, we will miss the human side of our profession. I feel very strongly that preservation science should be as much a social science as a materials science. In this regard we need research—targeted, focused research—on the sociology of learning and scholarship; on the acceptance and rejection of technology; on the behavior of organizations charged with creating, selecting, or acquiring information sources for long-term preservation; and on the politics of preservation within institutions—indeed, within societies—that do not value their own history.

I urge that, as we focus on technology research in the next couple of days, we do not lose sight of the broader political and social contexts within which scientific research must be carried on. Addressing some of the related political and sociological questions is a vital part of a preservation research agenda.

Paul Conway heads the Preservation Department at Yale University Library. He has served as Preservation Program Officer for the Society of American Archivists and as an archivist at the Gerald R. Ford Library and the National Archives and Records Administration. He earned a Masters Degree in History and a Ph.D. in Information and Library Studies from the University of Michigan.

THE ORGANIZATIONAL PHASE OF PROJECT OPEN BOOK

A REPORT OF THE YALE UNIVERSITY LIBRARY TO THE COMMISSION ON PRESERVATION AND ACCESS

DONALD WATERS AND SHARI WEAVER

JULY 1992

SELECTED EXCERPTS

"The Yale University Library is now organized to move ahead with Project Open Book, the conversion of 10,000 books from microfilm to digital imagery. In the first phase of the Project-the organizational phase — Yale established a Steering Committee, including several faculty members, and created a project team. In addition, Yale conducted a formal bid process and selected the Xerox Corporation to serve as its principal partner in the project. Xerox has identified for Yale the required equipment, software and services to complete the project, as well as their costs, and has proposed an ... implementation plan. The implementation will ultimately result in a conversion subsystem, browsing stations distributed on the campus network access to high-quality image printers. The process leading to the selection of the vendor helped isolate areas of risk and uncertainty as well as key issues to be addressed during the life of the project. The Yale Library is now prepared to select the material for conversion to digital image form and to seek funding, initially of the first phase and then for the entire project."

"Yale is motivated in Project Open Book to test and explore a set of hypotheses about the feasibility of digital imaging as a preservation tool. These working hypotheses are based, ultimately, on an "ideal" model of digital image documents in the library of the future. Among the key hypotheses are these:

* Microfilm is satisfactory as a long-time dium for preserving content;

* Digital imagery can improve access to recorded knowledge through printing and network distribution at a modest incremental cost over microfilm;

* Researchers will demand greater access to digital image libraries that contain thematically-related materials;

* Capturing and storing documents in digital image form is a necessary step leading to even further improvements in access (e.g., through the application of OCR)"

"As work proceeds to the next phases in Project Open Book, Yale recognized the need in the library community to find collaborative ways to address the key issues raised by the use of digital image technology. In particular, it needs to build a technical and organizational infrastructure of equipment, software, networks, and knowledgeable users and staff that spans multiple campuses and facilitates the reliable and cost-effective interchange of image documents. Building on its experience in Project Open Book, the Yale Library expects to contribute substantially to an understanding of the role of digital imagery in the library of the future and to the collaborative efforts needed to insure its effective use."

PRESERVATION OF ELECTRONIC RECORDS: ARCHIVAL PERSPECTIVES

CHARLES DOLLAR, *NATIONAL ARCHIVES*

I am delighted to be here and to participate in this symposium that is addressing preservation of material of enduring value. Ken Harris has strongly urged that I keep my remarks brief so I will endeavor to do this.

As many of you may know, I have had a long standing interest in electronic records and I am committed to the use of new and emerging information technologies because I think that ultimately they will provide many of the preservation tools we will need. Perhaps it may seem incongruous that I follow Lew Bellardo's presentation in which he offered an overview of the preservation program of the National Archives that largely focuses upon paper and wet chemistry technologies. The very fact that Lew and I are sharing the podium this morning reflects the complexity of preservation. We are not dealing with one storage medium or one set of problems and the National Archives, like the Library of Congress, is attempting to develop a multimedia or diversified approach.

I propose to do three things this morning. First, I will summarize briefly how information technologies are creating a new and different work environment. Second, I will introduce at least a debatable, if not discordant, note in the rather harmonious presentations this morning by offering my own viewpoint regarding the need to redefine preservation for electronic records. Third, I will briefly summarize the official position of the National Archives regarding optical media.

CHANGING WORK ENVIRONMENT

The convergence of information technologies in the last five years or so is on the verge of causing enormous changes in the way we work, play, socialize, organize, teach, and even make war. By the end of this century electronic information systems that support routine activities — at home, at school, at work, and in business, military, science, medicine, education, and government, among others—will have a dramatic impact on the work of archivists and librarians in the years ahead.[1]

At this point we have an incomplete sense of the ultimate impact this convergence of information technologies will have on the work of archivists and librarians. It is a safe prediction, I think, that the impact will be greater than we can possibly imagine today. Nonetheless, the outlines of an information technology oriented society are beginning to emerge. One dimension of this outline is the increasing displacement of paper based information technologies by electronic information technologies. I characterize this displacement as the changing form of documentation in which increasingly we will be working with electronic forms of records, books, and publications.

Despite the fact that for most of us, paper based information technologies and products still dominate our work, there is growing evidence of a major transformation underway. The Annual Survey of users conducted in 1992 by the Association for Information and Image Management reported that for the first time, in terms of expenditures between microfilm and digital imaging technologies, 53% of expenditures made across the industry were in the area of digital imaging technology, and about 47% were microfilm based. And the trend, many people believe, is going to increase the gap.

Equally as impressive is the assessment that ten years ago electronic formats accounted for only 10 percent of its business of *Chemical Abstracts* with the remainder being paper formats. By the end of 1990 electronic formats accounted for 48 percent of its business. Given this growth rate, the next decade will see electronic format accounting for as much as 95 percent of the business of *Chemical Abstracts*.[2]

At the Federal Government level, digital imaging technology applications increasingly are displacing paper. At least two factors help to account for this increase. First, digital imaging technologies can relieve agencies of the intensive labor burden of dealing with paper. Second, the use of digital imaging technologies will permit agencies to deliver better public service.

A second dimension of our information technology driven environment is the changing character of work. Increasingly, all of us — well, may be not all of us, but many of us find that the way we work is being changed by the information technology tools that are available to us. Electronic communication networks

are breaking down the barriers of time and space that traditionally have made it difficult for people widely dispersed to participate meaningfully in work activities. Distributed databases and electronic networks are promoting organizational decentralization while at the same time they are bringing people and resources together across time and space and thereby allowing them to work productively in ways not previously possible.

A third dimension of this emerging information technology convergence, which in the long run perhaps is the most profound, is the changing expectations that users have of those of us who provide information services. It is my belief, and I think it is a belief shared by many people, especially within the library community, that increasingly we will have to deal with users who are accustomed to dealing with the quick delivery of information services in the commercial or private section, and they expect those of us in archives and libraries to be able to provide the same kind of service. The implications of this for the ways we have traditionally delivered information services and products are enormous.

Now, if one accepts these premises, and I realize that they are somewhat debatable, nonetheless, if one accepts them for the purposes of my discussion this morning, it seems to me there are two implications for us. First, we can, as some people have argued, stay with low risk technologies, that we stay with microfilm — microfilms as established storage medium — and that we take material as it comes into us in digital form and place it on paper, or place it on microfilm, or even make paper copies. That is a low risk technology, and there's no question about that.

But the trade off, it seems to me, and the price that's being required to pay is exorbitant, because we lose all of the value-added benefits that come from the use of electronic information technologies. Furthermore, it precludes our being able to provide the kind of information delivery service that many people in the future will require of us. So it seems to me that — and again this is a personal viewpoint — we cannot turn our backs, as it were, to the use of information technologies. I would like to embrace them fully. Yes. I'll admit that's a rather bold, presumptuous position, but I do believe that all of us have to learn to live with, accept, and implement the emerging information technologies available to us.

Let me quickly turn now to the second theme of my remarks this morning. The fundamental problem that we all have with electronic information technologies is not technical but rather intellectual. One aspect of this problem is the need to redefine what the preservation of electronic material means.

The traditional North American focus upon the physical carrier of the information — paper, microfilm, and magnetic tape — offers little useful guidance for dealing with digital material in the 1990s, because the single most important problem is technological obsolescence. In order to deal with technological obsolescence we must shift the emphasis from preservation of the information carrier or physical storage media to the maintenance of access over time. This shift in emphasis, which is already underway in the archives and library communities, involves a fundamental reorientation of preservation approaches, methodologies, and practices.

Maintaining access to digital material over time is a question of readability and intelligibility. Readability means that the information can be processed on a computer system or device other than the one that intially created the digital information or on which it is currently stored. Typically, non-readibility involves some aspect of the storage device (a tape or disk) that is physically incompatible and cannot be read by a computer. This is generally called hardware obsolescence as storage devices and media used today will be incompatible with those likely to be developed in the future.

In contrast, intelligibility, which assumes readability as just defined, means that the information is comprehensible to a human being. Intelligibility may function at three levels. At the simplest level, it occurs when two computer systems either use or understand the same representation of the information but when the representation is presented to users it does not carry sufficient information (i.e., it is not self-referential) for a human to comprehend its content. Usually, this problem is associated with both coded and numeric data, and the intelligibility of such information can be assured by the use of documentation defining the values represented by the numbers and codes. The third level of intelligibility occurs when the two different software applications functioning in different computing environments can process the same digital data with the same results. Digital data that can be processed only by the original software application is called "software dependent" and this constitutes a major impediment to ensuring intelligibility over time, especially as software becomes obsolescent.

Addressing hardware and software dependence involves two activities: periodic recopying and migration to new generations of technology. Periodic recopying of digital information in order to stay current with

existing technology (e.g., from 6250 BPI tape to 3480/90 Class Tape Cartridges) offers an absolute guarantee of readability. As long as the volume of digital information is relatively small and the time between copying remains ten years or so, this is very attractive. However, periodic recopying every ten years or less can become a major financial burden, even when storage media costs are extremely cheap.[3] Data exchange standards, which support upward migration paths that bridge computer generations, potentially can extend the time between recopying from, say, ten years to twenty years.

Maintaining the readability of digital information over time does not guarantee intelligibility as software and operating systems become obsolescent. Nevertheless, it does provide the platform on which two different approaches to maintaining intelligibility can be developed. One approach would be to transfer all intelligibility problems to the future in the expectation that either users will be able to do reverse engineering of the original software or that software and operating systems will be smart enough to achieve intelligibility with little or no human intervention. Reverse engineering say, two hundred years from now, of software developed in the 1980s would require the collection and maintenance of extensive documentation of the original software, a task that is doable but vulnerable to a host of problems that are familiar to those who have worked with computer program documentation issues.[4] Reliance upon "smarter" computer software in the future presumes that no matter how much computer technology may change in the future it will be possible to achieve continuity of functionality.

A more realistic approach is to rely upon international standards that support interoperability and upward migration paths across technology generations. For example, a standard for interactive electronic documentation, such as the Information Resource Dictionary System, is intended to provide a bridge between otherwise incompatible software systems,[5] thereby extending the intelligibility of electronic records.

Ensuring the readability and intelligibility of electronic material over time through adherence to information technology standards involves techniques and tools that are substantially different from those with which most archivists and librarians are familiar. Because technology obsolescence is at the heart of problem of how to facilitate access over time to electronic material, we must develop technology migration strategies to deal with it.

OPTICAL MEDIA ISSUES

The National Archives current policy is to discourage the use of optical media for the storage of records of permanent value largely because the optical media industry is not yet mature and we know far too little about the critical issues of optical media. Over the last decade and a half numerous staff at the National Archives have monitored developments in optical media. The current focus of this activity is now in the Technology Research Staff where we are involved in trying to define what we call three critical problem areas.

The first is the longevity of optical media. The issue here is the life expectancy of optical media? Is it fifty years, is it a hundred years, thirty years, what is it? In some ways, this may be an irrelevant question, because technology obsolescence is going to overcome and bypass all of these issues of longevity of media, but nonetheless, it is an issue that many people believe is crucial. We have attempted to deal with the longevity issue by supporting work at the National Institute of Standards and Technology. With the support of NARA, NIST has developed a generalized standard test methodology that, as it moves through the standard setting process, can be sufficiently generalized that any vendor making a claim for longevity can say, "The test on which we base our claim was conducted in accordance with this standard."

This means that, unlike today, when claims about longevity are examined, there are different approaches used, different assumptions, that result in comparing apples to oranges. Our expectation is that this standard test will enable us to compare oranges to oranges or apples to apples, and maybe lemons to lemons.

The second area of optical media considered a crucial problem area for us is what we call data degradation. Because of the high storage density and the very low mechanical tolerances, errors in the process of reading CD-ROM or a WORM media, errors are very high, and so there are very strong and powerful error correction codes that are built in to compensate for this. Users can't tell that there's anything happening, because the error correction codes are automatically invoked.

The problem is that there is currently no easy way for a user to know the level of error correction activity that occurs, because, at a certain point, with the error detection, error correction algorithms, a maximum level of performance is achieved, and when

that level is reached, then a certain portion of a disk can become unreadable. The National Archives is supporting work at NIST to develop an approach for monitoring error correction activities and presenting that information in a usable form to users. This approach, which will be introduced as a draft standard, will provide users with information so that optical media can be recopied before parts of a disk become unreadable.

The third crucial problem affecting the long term usability of digital records, especially those stored on optical media, is to develop a migration strategy for moving digital material to new media and technologies as older ones are displaced. Because digital material is technology dependent and, therefore, is subject to technology obsolescence, the development and implementation of a migration strategy to ensure that digital records created or in use today can be both processed by computers and intelligible to humans in the 21st Century is absolutely essential.

Toward this end, the National Archives initiated a study last year entitled Digital Imaging and Optical Media Storage Systems: Guidelines for State and Local Governments in which the broad characteristics of a viable migration strategy were outlined. A follow-on study with guidelines for federal agencies is now underway and will be completed in mid-1993.

ENDNOTES

[1]I have reviewed technologies in some detail in *The Impact of Information Technologies on Archival Methods and Practices* (University of Macerata (Italy), 1992).

[2]Statement made on December 1, 1990 at a conference on the National Research and Education Network at the Harvard Kennedy School. Cited by Henry Perritt in "Electronic Publishing Formats," *Proceedings, Conference on Electronic Publishing Standards and Formats in the Fields of Law and Accounting* (National Center for Automated Information Retrieval (May 1991): 3.

[3]While the per byte storage cost for media continues to decline, the volume of digital information that requires periodic recopying will grow dramatically and the key challenge will be the relative slow data transfer rate of available devices. Given a substantial increase in the volume of digital information, slow transfer rates may make it very difficult financially or time wise to copy the information to the next generation of technology.

[4]For a very early description of some of these problems, see Charles Dollar, "Documentation of Machine Readable Records and Research: A Historians' View," *Prologue: The Journal of the National Archives* 3 (Spring 1971): 27 - 31

[5]Incompatible software systems also includes software that has become obsolescent.

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TEMPERATURE AND RELATIVE HUMIDITY EFFECTS ON THE AGING OF CELLULOSE

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ABSTRACT

Accelerated aging often is employed to speed up the normally slow degradation of paper to rates which can be measured and studied easily. The use of accelerated aging introduces two problems: relating the accelerated rate to the rate under normal conditions, and more importantly, demonstrating that the aging process of materials subjected to accelerated aging is the same as that for materials aged naturally. One approach to the evaluation of accelerated aging conditions is to quantify the amounts of individual degradation products. Using the results from a matrix of accelerated aging conditions, one can determine whether the distribution of degradation products for a particular set of conditions is the same as that predicted for natural aging. A research project examining the effects of temperature and relative humidity on the aging of paper is currently underway.

AGING AND THE ENVIRONMENT

The rate and nature of the aging and degradation of cellulose and cellulosic materials such as paper depend critically on the environment. For instance, cellulose degrades much more quickly at high temperatures than at low temperatures, and ages differently under intense ultraviolet light than it does in the dark. The differences due to aging under different conditions can be determined readily if the aging conditions are quite extreme. The differences which are produced by aging within the range of environments which might be considered for storage or display in a museum, library, or archive, however, are much more difficult to measure. The principle reason is that cellulose is an extremely stable material, and its degradation under normal conditions is extremely slow. High quality paper can last for more than a thousand years, and the lifetime of even poor quality paper is measured in decades. This extremely slow rate of degradation means that only very small changes occur over time periods considered reasonable by most researchers. It can be very difficult to detect and measure such small changes. It is quite important either to measure or to be able to predict the rate and nature of these changes, though, because even very small differences in these already small changes can result in enormous differences in the ultimate lifetime of the paper.

If one could characterize and determine the nature and rate of degradation of paper as a function of the environment, then one could predict how changes in the environment would affect the aging of paper. Such information then could be used to determine the conditions most suitable for display and storage, or to evaluate the effectiveness of specialized storage conditions such as cold storage. Determinations of absolute or relative rates of degradation also are used to determine the permanency of materials or to judge the effectiveness of treatments which are intended to reduce the rate of degradation.

ACCELERATED AGING

One way to avoid the problem of measuring very small rates of degradation is to speed up the changes. This usually is accomplished by modifying the environmental conditions, and often involves increased temperatures. The resulting accelerated rate of deterioration of paper yields larger and more readily determined changes within reasonable time spans. The experimentally determined rates of change can then be extrapolated back to normal (or "natural") aging conditions to predict an absolute lifetime for the material. These extrapolations often involve large enough errors, however, that the results are not very useful. More often, relative rather than absolute aging rates are determined. Measurements of properties of paper samples before and after such accelerated aging can be used to determine the relative aging rates of, for instance, control and treated samples to determine the effectiveness of a treatment. The properties which are measured can be almost any properties of interest, such as strength, brightness, or stiffness.

Accelerated aging is an attempt to produce in a short time the effects of long periods of natural aging. The implicit assumption is that the results obtained under the modified or accelerated aging conditions

can be applied directly to natural aging, in other words, that the same results would have been obtained if the same experiment had been run at normal conditions for the much longer time periods required for an equivalent degree of degradation to occur.

Two questions arise from such an assumption. The first is whether the rates of accelerated aging of two different samples are related by the same factor to the rates of the natural aging of the samples. In other words, do the accelerated aging conditions speed up the aging process by the same factor in both samples? If not, then it is possible that the sample which degrades most quickly under normal conditions will degrade most slowly under the accelerated aging conditions.

The other, and more fundamental, question is whether the changes which occur during accelerated aging are the same as those that occur during natural aging and whether the results of accelerated aging bear any relationship at all to those of natural aging. The aging of a complex material such as paper is not a single reaction, but instead consists of a number of reactions, the rates of each of which are affected differently or to different extents by each of a number of factors. Reactions involving water may be the most important reactions at moderate or high humidities, but essentially stop during dry oven aging where the relative humidity may be only a few percent. Reactions which do not occur at all during natural aging may become important at very high temperatures.

Thus, the question is not whether just one reaction is accelerated by the same factor in two different samples, but whether the relative rates of a number of reactions remain the same. In addition, accelerated aging conditions must not produce changes which would not occur during natural aging.

These two requirements for the equivalence of two sets of aging conditions can be summed up as follows: Two sets of aging conditions are equivalent if and only if

1. The same reactions occur during both sets of aging conditions; and

2. The relative rates of each reaction are similar under both sets of aging conditions.

In other words, accelerated aging conditions should speed up all reactions by the same factor without introducing new reactions in order to simulate natural aging accurately. This is easy to state, but not to test experimentally. Most tests used to evaluate the results of aging are not reaction-specific, but involve the measurement of properties which can be affected by a number of reactions. These tests measure degradation without determining how it was produced. For example, changes in the strength of paper can be affected by numerous reactions including oxidation, hydrolysis, crosslinking, and chain scission. Thus tests which can be used to evaluate the results of aging are not necessarily useful in trying to determine whether the aging conditions themselves are valid. Combinations of tests and conditions can be used to follow types of reactions, but few tests allow one to follow individual reactions. For example, the overall contribution of oxidative reactions can be determined by varying the oxygen concentration during aging experiments, but it is much harder to determine the relative importance of each of the many oxidative reactions.

THE EVALUATION OF ACCELERATED AGING CONDITIONS FOR PAPER

One way to follow individual reactions is to determine the concentrations or relative quantities of individual reaction products. If changing the aging conditions produces changes in the types or relative amounts of degradation products, then the reactions producing them are not occurring to the same extent. A series of experiments with different sets of aging conditions could determine ranges in which the distribution of products of the aging process were similar enough that the aging conditions could be considered equivalent.

Previous articles outlined a method of extracting, quantifying, and characterizing some of the monosaccharide degradation products of paper, and discussed the results obtained by aging paper samples under different sets of aging conditions[1,2]. The conditions represented a very wide range of temperatures and relative humidities, and included moist aging at 90°C and dry oven aging at 90°, 120°, and 150°C. It was shown that the degradation product mixture varied dramatically with the conditions. Although basically the same products were present under all conditions, the distribution of these products was very different. Glucose, which is produced by the reaction of cellulose with water, was the major product at high humidity, but only a minor product at low humidity. One product produced in minor amounts at low temperatures was generated in much larger amounts at 150°C. These results demonstrated that aging experiments at very low and very high relative humidities are not compa-

32

rable, and that the upper limit below which aging could still be comparable to natural aging is less than 150°C.

These initial experiments used rather extreme conditions for two reasons. One was to test the technique, to determine if it was feasible to follow the aging process of paper by the analysis of extractable degradation products and to determine if the results could be used to detect differences in aging conditions. The second reason for using relatively high temperatures was so that results could be obtained within a short time period. These limited experiments did not provide enough information, however, either to extrapolate the results to natural aging or to determine what conditions most accurately simulate natural aging. Once it was shown that the technique worked and could be used to evaluate differences between aging conditions, it was decided to embark on a much more ambitious project.

CURRENT RESEARCH

The present project involves the aging of paper samples in a number of different environments of controlled moderate relative humidities and temperatures. The temperatures range from 50°C to 90°C in 10°C intervals, with nominal relative humidities of 30, 50, and 75% (exact values varied due to instrumental design, but were constant for each set of conditions). The relative humidity is controlled by saturating air with water vapor at the appropriate dew point temperature and feeding it to the heated sample chamber. A total of 7 environmental chambers were constructed, each with a different (adjustable) temperature and relative humidity. This is not enough sample chambers to cover the entire matrix of conditions planned, so successive sets of samples will be aged as the aging of other sets is completed. Ten samples each of Whatman #1 filter paper and a high quality cotton paper were initially placed in each chamber. One sample of each was removed at intervals, with each total time roughly 1 1/2 times the previous one. Because of the relatively low temperatures involved, these samples must be aged for much longer periods of time than those in the first experiment, with lower temperature experiments running longest. The following table lists the sample conditions and total aging times for the sample sets either finished or still under way.

These samples will be analyzed using the same basic method of extraction of the degradation products, followed by separation and quantification with gas chromatography. This will allow the rates of a number of different individual reactions to be determined as a function of temperature and relative humidity. Extrapolation of this data to normal aging conditions will yield predicted reaction rates and degradation product mixtures for naturally aged papers, and will also allow the prediction of how changes in temperature and relative humidity will affect the aging of paper within a range of temperatures and relative humidities which might be considered for storage and display. In addition, the product mixture predicted for natural aging can be compared to the results for the accelerated aging tests to determine a range of conditions for which accelerated aging reasonably simulates natural aging, and which conditions most closely approximate natural aging.

In addition, the samples also will be tested by other methods, including some which are in common use for the evaluation of the results of accelerated aging. The tests will include strength, fold endurance, and optical measurements, as well as general chemical tests such as copper number. This will allow correlations to be made between the different tests, determine how the results of each test are affected by the conditions of aging, and help to determine what types of reactions affect each property.

SUMMARY

Because the degradation of paper is relatively slow, research involving the permanence of paper often requires the use of some form of accelerated aging. There are many tests that are suitable for evaluating the effects of aging. Most, however, are not suitable for determining whether the aging conditions adequately reproduce natural aging. This is because they measure properties which depend on more than one of the many reactions which take place, and cannot be used to determine if the entire process is speeded up evenly without exaggerating or minimizing the roles of individual reactions. This problem is avoided if the rates of individual reactions can be determined. This can be accomplished by quantifying the amounts of individual degradation products. Extrapolation of the results to normal aging conditions results in a distribution of degradation products expected for the range of conditions encountered during natural aging. The results of accelerated aging can be compared with this predicted mixture to see if a specific set of aging conditions adequately simulates natural aging.

REFERENCES

1. David Erhardt, David von Endt and Walter Hopwood, "The Comparison of Artificial Aging Conditions Through the Analysis of Extracts of Artificially Aged Paper", *Preprints* of the 1987 Vancouver conference of the American Institute for Conservation.

2. David Erhardt, "Paper Degradation: A Comparison of Industrial and Archival Concerns", in *TAPPI Proceedings: 1988 TAPPI Paper Preservation Symposium*, TAPPI Press, Atlanta, 1988, pp. 83-91.

David Erhardt earned his Ph.D. from the University of Maryland in 1977, and was a Research Associate at George Washington University Medical Center from 1978-1979. He is presently Senior Research Chemist, Conservation Analytical Laboratory, Smithsonian Institution. He has been with CAL since 1979. His field of specialization is organic chemistry of museum objects.

Table. Aging Conditions and Times for Sample Sets

Temperature C	Relative Humidity %	Longest Aging Time (days)
50	50	1260 (so far)
60	30	1260 (so far)
60	76	1280 (so far)
70	50	1280 (so far)
80	32	1280 (so far)
80	73	278
90	50	278

PRESERVATION AT CORNELL UNIVERSITY

ANNE KENNEY, *CORNELL UNIVERSITY*

I am Anne Kenney. I am the associate director of the department of preservation and conservation at Cornell. I'm also the co-director of the Cornell-Xerox joint study on digital preservation. I've also brought some show and tell items. I have a sample of a book that we've scanned and digitized that I'd like to pass around.

For the past two and a half years, we've been experimenting with a prototype system for scanning brittle books as digital images at 600 dots per inch resolution, storing them as TIF 5.0 images, using Group 4 CCITT fax compression and printing at 600 DPI facsimiles on the Xerox Docutech printer. During the course of this project, we've scanned 950 brittle books, created an electronic library of the digital files and made the files available over Cornell's network for printing, storing and viewing on a prototype view station. Paper facsimiles for all of the volumes were created, bound and sent to the stacks to replace the deteriorating originals and the digital files and the paper facsimiles were cataloged both on RLIN and Cornell's local catalog (NOTIS).

A print request server was developed that will enable researchers in the privacy of their own offices to review a document control structure which will outline the structure of a book, highlighting its key components, such as its table of contents, chapter divisions, index, and will allow the reader to request a printed version of the entire book, parts of the book, or individual pages.

The joint study was guided from the outset by a number of principles. The first was that the use of digital technology must be both cost effective and result in products of sufficient quality to be considered viable for the preservation of deteriorating library materials. The second principle was that convenient access to preserved materials is as essential as preservation and that digital technology's greatest promise as a preservation option is to improve access.

A substantive evaluation of its impact on use, however, may require the development of a critical mass of material in digital image form that is easily available to researchers. The third guiding principle was that investigation into the use of digital technology could only be undertaken from a spirit of collaboration.

In our project, the library and information technologies were equal partners. I spent the first year apologizing for not being a techie, only to realize that my expertise was vital for translation into a preservation context. Cornell also fully participated in the development and testing of the system with the Xerox Corporation and we were fully represented on the product development team. We were also supported in this work by the Commission on Preservation and Access which lent us not only financial assistance, but provided us I think with moral support that lent legitimacy to our investigation.

Further investigation into the use of digital technology should include the participation of a broad range of research libraries, university technology organizations, groups that facilitate national programs, standards setting bodies, technology vendors, funding bodies and service bureaus that provide scanning, filming and other services.

In keeping with the spirit of collaboration, every attempt was made in our project to use standards that would promote future exchange of digital material over networks. For example, image file formats, data compression standards and network protocols that were proprietary in nature were avoided in the design and architecture of the system.

A final guiding principle was to rely to the extent possible on technology that was readily available as product or near product and that was developed for the broader marketplace, first, so that it would be widely available to other research libraries and, second, so that its existence would not depend solely on library applications.

The primary conclusions from our study were that digital technology provides an alternative of comparable quality and lower cost to photocopy and, subject to the resolution of certain issues, digital technology offers a cost effective adjunct or alternative to microfilm. The resolution of these issues will include such things as the development of mechanisms for dealing with the obsolescence associated with the rapidly changing technology and the definition of quality that would be suitable for the use of digital techniques.

Digital technology has a potential to enhance access to library materials and to provide links between the library catalog and the material itself. In the future, this technology could permit the viewing of books on work stations, browsing collections from several institutions at the same time, and the production of a print on demand for paper facsimile.

We also concluded that the infrastructure developed for the library preservation and access activities could support other application in the electronic dissemination of information and, at Cornell, we are involved in a number of experiments for the electronic dissemination of journals, through work at the book store and Cornell press for reprint series.

The Cornell / XEROX / Commission on Preservation and Access Joint Study in Digital Preservation, Report: Phase I is available from the Commission on Preservation and Access, 1400 16th Street, N.W. Suite 740, Washington, D.C. 20036. An Executive Summary of the report is provided:

Cornell University and the Xerox Corporation, with the support of the Commission on Preservation and Access, have collaborated for the past two years in a Joint Study to investigate the use of digital technology to preserve library materials. The primary emphasis of this study has been on the capture of brittle books as digital images and the production of printed paper facsimiles. Of equal interest, however, has been the role of digital technology in providing networked access to library resources, and preliminary work in this area has also been accomplished.

The Joint Study has led to a number of conclusions regarding preservation access, electronic technology, and the role of the library. In particular, participation in this study has convinced Cornell of the value of digital technology to preserve and make available research library materials. Such digital preservation presents a cost effective alternative to photocopying, and — subject to the resolution of certain remaining problems — a potential adjunct or alternative to microfilm preservation. The greatest promise of digital technology as a preservation option is to improve access to materials. Cornell expects to work with others to find ways to resolve the remaining issues surrounding the use of digital technology.

Anne R. Kenney is the Associate Director of the Department of Preservation and Conservation at Cornell University Library. She is the project director of a number of preservation microfilming projects funded by the National Endowment for the Humanities and co-manager of the Cornell/Xerox Joint Study in Digital Preservation, which is partially funded by the Commission on Preservation and Access. Prior to coming to Cornell, Anne was Associate Director of the Western Historical Manuscript Collection and University Archivist at the University of Missouri-St. Louis. She is a Fellow of the Society of American Archivists (SAA) and the current president of SAA.

PHOTOGRAPHIC MATERIALS SCIENCE AT THE CONSERVATION ANALYTICAL LABORATORY

MARK H. MCCORMICK-GOODHART, *CONSERVATION ANALYTICAL LABORATORY, SMITHSONIAN INSTITUTION*

The Conservation Analytical Laboratory (CAL) established a photographic materials science program in 1988. Fundamental research is conducted on the deterioration of photographic materials, and assistance is given to conservators and curators at the Smithsonian Institution with material analyses, process identification, and preservation issues. Results from two areas of recent research are summarized:

THE DETERIORATION OF WET-PLATE NEGATIVES

The National Portrait Gallery has 5445 wet-plate negatives made by the Mathew Brady Studios during the 1860s. These plates now comprise the Frederick Hill Meserve collection and share a common heritage with wet-plate negatives at the Library of Congress and at the National Archives. Bulk glass composition was determined by electron microprobe analysis and confirmed that numerous batches of predominantly soda lime glass were used by the Washington and New York studios over the span of several years. However, the chemically deteriorated images resided on only two batches of glass, and these plates account for 11% of the collection. The two batches were less durable glass, characterized by high alkali oxide content and lower alkaline earth oxide content. Sodium leaching from the glass into the collodion and varnish layers promoted cracking and flaking, and in the most severe cases, total saponification of the varnish. The saponification reaction was identified by FTIR analysis of the degraded varnishes. No plates were found where present image quality could be attributed solely to cellulose nitrate degradation or to poor processing by the Brady studios. Because the varnish and collodion layers are very thin (typically less than 10 microns total), comparatively small amounts of glass corrosion at the collodion-glass interface initiate chemical degradation of the image coatings. Nevertheless, the wet-plate process was executed on reasonably stable glass in most cases, and these images have endured remarkably well.

COLD STORAGE ENVIRONMENTS FOR PHOTOGRAPHIC MATERIALS

The benefits of cold storage for slowing the deterioration of photographic materials, especially chromogenic color systems, are widely recognized. Unfortunately, implementation is challenging and much difficulty stems from the methods of achieving and maintaining the recommended humidity levels within the cold storage facility. Concerns about stress on the objects as they are cycled between storage and user environment have also been raised.

Under the direction of Dr. Marion Mecklenburg, CAL does extensive materials testing of polymers. The response of multi-layered polymeric structures to changes in temperature and relative humidity have been successfully predicted at CAL by computer modeling based on the method of finite element analysis. The first application of the computer modeling technique was in the study of paintings. During 1992, the same methodology has been extended to photographic materials with outstanding results. The dimensional response and internal stress in a Cibachrome color print was accurately calculated as it responded to changes in relative humidity and temperature. A 30 percent change in relative humidity was of particular interest, because it can easily occur in the real world when a film is conditioned to low relative humidity prior to or upon entering cold storage. A stress level over 4000 PSI was developed in the Cibachrome gelatin layers due to this drop in relative humidity. Lowering temperature from 24°C to -18°C caused a 1200 PSI stress increase. The stress levels are additive when changes occur in both temperature and humidity. Also, the general behavior modeled for Cibachrome is expected to hold true for all photographic materials containing gelatin layers.

New photographic materials can withstand stresses in excess of 5000 PSI without crack initiation or delamination, but these levels cannot be ignored, especially where older samples with weakened adhe-

sion are present in a collection. For example, the "channeling" phenomenon in deteriorating acetate base film collections can be triggered. The important point for cold storage designs and for storage and use environments in general is that humidity induced stresses are best managed by avoiding moisture desorption paths. Often utilized conditioning procedures establish moisture equilibration but do not eliminate the majority of the active stress.

Finally, the practical chemical benefits of low humidity versus moderate humidity cold vaults were re-examined using existing dye stability data. The objective was to determine how much chemical stability would really be sacrificed if the humidity controls were raised, for example, from 30%RH to 50%RH. An important aspect of this evaluation was that time out of storage was included in the overall rating. A table accompanies this report. It lists effective dye fading rates for various temperature, relative humidity, and time out of storage combinations. Small amounts of time out of storage were determined to play a critical role in the overall effectiveness of cold storage when temperatures approach commercial freezer levels of —18°C. One or two extra days per year out of storage can cancel out the chemical stability improvement that would be expected by setting low relative humidity within the vault or sealed package. As the storage temperature increases, time out of storage becomes less significant. Low relative humidity then appears to give a chemical benefit. The paradox is that this same benefit can be met at moderate humidity simply by selecting a slightly lower temperature value.

In conclusion, the fading rate data demonstrate that the temperature parameter can be independently set to achieve any sustainable level of chemical stability. Coincidentally, the stress analysis shows that lowering temperature is also far less stressful than lowering humidity. Therefore, the humidity parameter seems better suited to the purpose of managing mechanical stress rather than fine tuning chemical stability goals. None of the facts presented in this report justify the acceptance of high humidity conditions. High humidity conditions are well documented in terms of their danger to photographic materials, but an analytical approach that considers both chemical and structural stability does provide a rational basis for understanding the total role of the humidity and temperature parameters. Hopefully, this research will contribute to a greater understanding of useful storage and exhibition environments for photographic collections.

RELEVANT PAPERS

M.H. McCormick-Goodhart, "An Analysis of Image Deterioration in Wet-Plate Negatives from the Mathew Brady Studios." *Journal of Imaging Science and Technology*. Vol. 36, No 3., 297-305, 1992.

Submitted or In Press:

M.H. McCormick-Goodhart and M.F. Mecklenburg, "Cold Storage Environments for Photographic Materials." Submitted to the *Journal of Imaging Science and Technology*. June, 1992.

M.F. Mecklenburg, C.S. Tumosa, and M.H. McCormick-Goodhart, "A General Method for Determining the Mechanical Properties Needed for the Computer Analysis of Polymeric Structures Subjected to Changes in Temperature and Relative Humidity." *Materials Issues in Art & Archaeology III*. Materials Research Society Proceedings, Vol. 283, P.B. Vandiver, J. Druzik, G.S. Wheeler, and I.C. Freestone, Eds., Pittsburgh, Pa., (in Press, 1992).

M.H. McCormick-Goodhart, "Glass Corrosion and its Relation to Image Deterioration in Collodion Wet-plate Negatives," *Conference '92: The Imperfect Image, Photographs their Past, Present and Future*. The Centre for Photographic Conservation: London, England (in Press, 1992).

Mark H. McCormick-Goodhart joined the Smithsonian Institution in 1988 as a research photographic scientist at the Conservation Analytical Laboratory. He holds a B.S. degree in Photographic Science from Rochester Institute of Technology, and was formerly employed by Energy Conversion Devices, Inc., from 1976 to 1988, where he was granted eight U.S. patents related to non-silver film and electronic imaging technology. His present research concerns the effects of environment on structural properties of photographs, and cold storage of photographic materials.

EFFECTIVE FADING RATE TABLE†

TIME OUT OF STORAGE††

(days per year)

STORAGE CONDITION TEMP(°C),	RH	0 days	1 day	2 days	5 days	10 days
24	60	0.5	0.5	0.5	0.5	0.5
24	40	1.0	1.0	1.0	1.0	1.0
24	15	2.0	2.0	2.0	2.0	1.9
15	50	2.3	2.3	2.3	2.3	2.2
15	40	3.3	3.3	3.2	3.2	3.1
15	30	4.3	4.3	4.2	4.1	4.0
7	50	7	7	7	7	6
7	40	10	10	10	9	8
7	30	13	13	12	11	10
2	50	14	13	13	12	10
2	40	19	18	17	15	13
2	30	25	24	22	19	15
-3	50	26	25	23	20	16
-3	40	37	34	31	25	19
-3	30	49	44	39	30	21
-10	50	71	59	51	36	24
-10	40	100	79	65	42	27
-10	30	132	97	77	47	29
-18	50	216	136	99	55	31
-18	40	305	166	114	59	33
-18	30	402	192	126	62	34
-26	50	707	241	145	66	35
-26	40	1000	268	154	68	35
-26	30	1319	286	160	69	36
"Perfect" Vault		∞	365	183	73	37

†Average dark fading rates for chromogenic color dyes relative to an environmental condition of 24°C, 40% RH. Table values are reciprocals to the effective fading rate. ††The standard condition (24°C, 40% RH) was assumed during the time that an object is out of cold storage. Underlined table values correspond to rates and conditions listed in "Conservation of Photographs", Publication No. F-40, Eastman Kodak Co., 1985. All other values in the 0 days/year column are interpolated from the primary data.

ABBEY PUBLICATIONS, INC. RESEARCH-ORIENTED ACTIVITIES

ELLEN MCCRADY, *ABBEY PUBLICATIONS, INC.*

This corporation was set up to encourage all aspects of preservation, and it does this by gathering and disseminating information to the people who can put it to best use—professional practitioners, suppliers, government officials, and researchers. Essentially, Abbey Publications functions as a special library, serving a widespread constituency. It publishes the *Abbey Newsletter* and the *Alkaline Paper Advocate,* both of which report new research findings. As editor, I stay in touch with researchers here and abroad, sending them literature they have requested or may not have seen, and asking them for news and reprints. Sometimes I critique manuscripts not intended for my own newsletters, and sometimes I translate (or have translated) significant material from other languages, for publication in the *Abbey Newsletter* or one of its supplements. I give special attention to the field of alkaline and permanent paper.

The field of preservation has many unsatisfied information needs which many people are now trying to satisfy through outreach efforts, publications, Email, formal training, conferences and so on. My emphasis is on indexing and reviewing the best of the existing literature and making it available, rather than on providing leaflets and information for the general public. I intend to index a number of professional publications to make them more useful to book and paper conservators and preservation people; I also intend to provide a faster, more effective document delivery service than the one we have now, which uses mail, fax and Email.

Some large research-related projects I have worked on over the past two years are:

1. The AIC Vocabulary Control Committee, on which I served as a member. The committee tried to produce a thesaurus, and found out that this is a lot of work. I purchased thesaurus-building software for use in the office, to make indexing and retrieval easier and more consistent, but have had no time to learn how to use it.

2. The Abbey Classification Scheme, by which all our information is arranged and indexed. This is over ten years old and ten pages long, not counting the index. Major expansions take place whenever large numbers of abstracts, references or literature are classified or added to the files and shelves. In the last year or so, the sections dealing with paper research (3B1) and paper conservation (3B2) were expanded and made more rational.

3. "The Best of Abbey," a list of the best 10% of *Abbey Newsletter* articles since 1975. This was requested by Lourdes Blanco originally, but there was also one request from Germany and one from Carlo Federici. They have permission to reprint or translate anything in the compilation. This would be more useful if it were supplemented by an inclusive index of all back issues. It would also, of course, be an index to the publications, products, people, conferences and so on that were mentioned in the newsletter.

4. One database of alkaline paper mills, and another database of permanent papers, which are maintained through telephone and mail surveys.

5. A subject index of 215 student research reports on book and paper conservation from the ICCROM bibliography of theses, dissertations and research reports in conservation.

Ellen McCrady's field of specialization is preservation of library and archival materials, with the emphasis on paper-based materials. In 1966, after eight years' experience as a librarian, she started a new career as bookbinder, which led to editorial and publishing work in preservation, and an advanced certificate from Columbia University (1984). She worked for two and a half years as a preservation administrator at Brigham Young University. She is currently the editor of *The Abbey Newsletter* and *Alkaline Paper Advocate*. She has received certificates of appreciation from AIC (1987) and from ALA (1992).

PRESERVATION AT THE UNIVERSITY OF CONNECTICUT

JAN MERRILL-OLDHAM, *UNIVERSITY OF CONNECTICUT*

Lurking in one of the four giant file cabinets that threaten to swallow up my office in the University of Connecticut's Babbidge Library is a fat file labeled "Research and Development — Issues — Preservation." I had to smile as I pored over the contents of that file in preparation for attending this promising meeting. It includes, among other things, list after list of unmet preservation research needs, as well as a number of statements reflecting librarians' and archivists' concern about a perceived lack of sufficient scientific evidence upon which to base critical preservation-related decisions.

These documents were prepared at various times by various people for officers of such organizations and institutions as the American Library Association, Association of Research Libraries, Society of American Archivists, Library of Congress, Commission on Preservation and Access, and the National Institute for Conservation. (As I look back, the Preservation of Library Materials Section of the American Library Association seems to have prepared enough lists of research questions to insulate a two-bedroom ranch house.) The communications are all irrepressibly hopeful. The letter that I sent to Dr. Peter Sparks just about 9 years ago, when he was Director of the Library of Congress Preservation Office and I, chair of ALA's Physical Quality of Library Materials Committee, outlines "10 issues of widespread concern," and closes thus: "We hope that some [of these research topics] will be included in the long-range agenda for the Preservation Research and Testing Office."

I am sure that this audience would not be surprised by the persistent recycling of most of the research questions that have been compiled over the years by the preservation community. They were revisited again a couple of weeks ago at a science workshop sponsored by the Commission on Preservation and Access. This gathering privileged fourteen preservation managers with a first time opportunity to work directly, for what amounted to two full days, with four scientists. I shouldn't speak for the group, but am willing to go fairly far out on a limb and suggest that the meeting was enlightening for all of us. I came away from it having entirely reordered the directory, subdirectories, and files that comprise my mental data base manager on the topic "Research and Development —Issues— Preservation." What follows is my current understanding of our situation. I'm sure that between now and tomorrow I will either have tinkered with it, or completely reconstructed it.

We have not studied, adequately, many of the issues that are most basic to developing intelligent preservation programs in libraries and archives. At what percentage should relative humidity be maintained in a closed stack area containing mixed collections of papers, books, photographs, and other materials that comprise general research collections? How much should RH be allowed to fluctuate on a daily basis? How do we address the presence of mold in research collections? At how many dots per inch must a document be scanned to produce, from digitized data, an archival backup that meets existing standards for preservation microfilm?

We have not examined our research needs in a way that suggests national priorities, and that would provide us all — scientists, consumers of the by-products of science, and potential funding agencies — with a map that makes sense of a very large landscape, that guides us towards reasonable consensus, and that creates a climate wherein progress is manageable. Nor have we a forum in which such work could be accomplished.

Where scientific research has been conducted, the results are not always translated into readily available technologies. It doesn't help to know how long it takes to kill cockroaches or silverfish with pure nitrogen if I can't purchase such a service.

As an adjunct to these research needs, there are associated information needs. The preservation literature is wide ranging and diffuse. It covers many largely unrelated technologies: climate control in buildings (including management of temperature, relative humidity, light, and gaseous and particulate pollutants); single-item conservation of wildly diverse media; reproduction by microfilming, photocopying, photographing, digitizing, and other means; and commercial library binding (an industry that is characterized by greater complexity and more unresolved technical issues than you might guess).

Discovering what is already known, in this broad arena, is a daunting challenge for the aging preservation manager. I can only guess, from the questions that are asked over the Conservation Distribution List so ably managed by Walter Henry at Stanford University, what the process of discovery must entail for those who are new to the field. We need a well-organized, current, annotated bibliography of preservation-related information resources that can help us track the key documentation, including seminal research findings, that should inform our work. An on-line service would be optimal; a CD-ROM product issued periodically, a great leap forward.

The juxtaposition of the Commission-sponsored science workshop and this Library of Congress-sponsored round table is auspicious. To be very unscientific about the matter at hand, no better opportunity has yet presented itself for laying our cards on the table and searching for signs that could help shape a plan of action for the future.

Jan Merrill-Oldham is Head of the University of Connecticut Libraries' Preservation Department, responsible for developing and managing a comprehensive preservation program for the University Libraries and Archives. She has been active in the field of preservation librarianship for about 12 years. She writes, teaches, consults, and serves in various capacities on committees sponsored by such organizations as the Association of Research Libraries, American Library Association, Commission on Preservation and Access, and the Northeast Document Conservation Center.

42

SCIENCE AND PRESERVATION DILEMMAS

CAROLYN CLARK MORROW, *HARVARD UNIVERSITY*

During my first three years as preservation librarian at Harvard, there were three instances during which the implications of an inadequate research and development infrastructure were highlighted as I attempted to make intelligent decisions about the program. As I reflect back on these experiences, it becomes clear that we are often forced to operate our programs on conventional wisdom, theoretical models, old paradigms, and without the benefit of cutting-edge scientific developments and cross fertilization of scientific specialties.

Within the first month after my arrival in September 1989, a team of architects, engineers, capitol planners, and curators met to review the final parameters of the first phase of the renovation of the environmental control system for the Houghton Library, Harvard's main rare books library. A major dilemma was that the preservation literature recommended a constant relative humidity, year-round, of 50%. Not only was this difficult and expensive to accomplish, but nearly impossible with an older masonry building such as the Houghton Library. While every preservation article contained the same recommendation, the footnotes citing actual research to support this recommendation were, as we all know, almost non-existent. In addition, a few years earlier, the University had scraped its plans to air-condition the Widener Library, which holds the humanities and social sciences collection of 3.5 million volumes in part because of the same conventional wisdom of 50% relative humidity year-round.

A second science issue arose at the end of my first year on the job as we prepared to add a second 2-million-book capacity unit to the Harvard Depository, our off-site storage facility. During the discussion of the effects of seasonal and diurnal temperature and humidity fluctuations, I brought out Donald Sebera's article on the "isoperm theory." Don's theoretical model engaged us; it offered us the opportunity to combine the implications of compact storage of cellulosic materials with the cost benefits of using the region's natural low winter temperatures to preserve materials—aiming for 50-55 degrees F for the majority of the year, while during the summer months we would allow the building temperature to gradually rise to 65 degrees F. But no matter how engaging a theoretical model, it is scary business to formulate long-term policy on a untested model. The work to test the impact of this model remains on the preservation research agenda.

Our third science dilemma began in winter 1990, when we launched a university-wide task force to take advantage of twenty years of research and development of mass (whole book) deacidification technology. We decided that we would not do any additional research because it seemed that enough had been done already. We went on site visits to the vendors' facilities. We had sample materials treated. We did an extensive literature search and charted what was known and unknown about each process. We contributed funds to a scientific study underway at the Canadian Conservation Institute.

Meanwhile, Andrew Barron, a Harvard chemistry professor on our task force, and his post-doctoral associate Andrew MacInnes, decided to apply spectroscopic analysis techniques to deacidified paper to identify the nature of the alkaline reserve. [Modern spectroscopic techniques were being used in materials chemistry to support the development of superconductors and semi-conductors.] Their analysis showed a uniform distribution of zinc oxide buffer through the paper depth in <u>uncoated</u> paper—an expected result; however, their analysis also showed that the DEZ molecule does not penetrate the coating to reach the acidic core of coated paper. These results took us by surprise and also opened up a whole new line of questioning about coated paper and deacidification. The Barron and MacInnes investigation was a departure from traditional paper testing methodologies and their work illustrated the added value of collaboration and cross fertilization of scientific specialties.

Carolyn Clark Morrow is Malloy-Rabinowitz Preservation Librarian in the Harvard University Library. She is responsible for developing and administering a network of preservation activities, programs, and shared services for the benefit of the 94 libraries in Harvard's decentralized library system. In FY 1992 there were 90 staff engaged in preservation activities librarywide with expenditures of $3.5 million.

THE PRESERVATION CONFERENCE IN CHICAGO, MAY 1992

MARTIN RUNKLE, *UNIVERSITY OF CHICAGO*

Many of us in the research library community have the sense that there is room for more coordination, cooperation, and collaboration in our preservation efforts than we have achieved so far. It was this sense that led Gerald Munoff, who is Deputy Director of the University of Chicago Library, to seek the cosponsorship of the Association of Research Libraries for a preservation planning conference in Chicago.

The Preservation Planning Conference was intended to assist the research library community to advance the planning for a comprehensive North American preservation program for research libraries. The purpose of the Conference was to 1) identify the needs that ought to be addressed in a comprehensive program for research libraries, and 2) identify a strategy for addressing those needs.

The Conference was held May 27-29, 1992. An Advisory Connittee, chaired by Mr. Munoff, helped develop the Conference. Conference participants included library directors, collection development officers, and preservation officers from 16 ARL libraries with established preservation programs, and representatives from organizations with an interest in preservation, such as the Commission on Preservation and Access (CPA), the Council on Library Resources, the Research Libraries Group (RLG), and the Center for Research Libraries (CRL). The Conference was structured around large and small group work.

The Conference focused on the components of the overall preservation environment that involve shared, coordinated activities. Work progressed from articulating a vision, identifying key issues and operational components, and planning for action.

A vision statement for a North American preservation program for research libraries describes what the research library community hopes to accomplish collectively in preservation in the next five to ten years. Key points from the participants' vision include:

— The scope of the preservation problem is such that the most effective effort is a coordinated preservation program that responds to local and shared needs.
— Information would be made available to users in appropriate formats.
— Economies of scale, standardization, and other benefits of cooperative action would be realized.
— Research, development, and application of technology would be encouraged.
— Partnerships among research libraries, users, resource allocators, and others would be advanced.

The key issues that were identified include the following:

— Criteria for selection and funding, since everything can't be saved.
— Balance between local and shared needs.
— Preservation of electronic media.
— Digitization as a preservation technology.
— Paper as an archival medium.
— Balance between preventive and remedial measures.
— Relationship between preservation and access.
— Cost and access models in preservation.

The operational components that need to exist in a comprehensive North American preservation program include the following:

— Training and education of preservation professionals, other library professionals, and users.
— Research and its interpretation.
— Development of standards.
— Management information, including cost/benefit analyses.
— Bibliographic access to preserved materials.
— User involvement in preservation.
— A preservation services infrastrucure.
— Collaboration among those concerned with the preservation of research library materials.
— Public policy, advocacy, and fundraising.
— Selection of materials to be preserved.

The Conference concluded with action planning

to define the agenda for a coordinated North American preservation program and to move it forward. Broad options for management and coordination range from (1) merely continuing the status quo (defining the aggregate of present activities as the North American program), to (2) establishing an entity that might coordinate component activities, to (3) establishing an entity whose responsibility it is to implement the program. Desirable characteristics of a new entity, if one were to be established, include a broad-based sense of community, involvement of a variety of people at various intensities of participation, accountability, and collective decision making and priority setting.

The following action proposals were made:

— Keep the status quo.
— Establish another organization or body to move the agenda forward, perhaps a coa lition for preservation along the lines of the Coali tion for Networked Information.
— Work with a structure that exists already; bring the agenda home to an existing organi zation. ARL, CPA, and RLG are the promi nent possibilities.

Most of the conference participants agreed that some ongoing forum to discuss preservation is needed by the research library community, and the existing organizations are not providing it. A new organization may or may not be necessary, but some opportunity for continuing discussion should be provided. There are multiple options to provide an ongoing forum to discuss preservation and to move forward an agenda for preservation. Participants were unwilling to define the forum at the Conference, since they did not yet have full view of what should be accomplished.

Therefore, the Conference participants resolved that a task force be established to develop proposals. The ARL Preservation Committee members present at the Conference were asked to convene a task force to develop options and present them to Conference participants. The task force is to consider process (how to move the program forward) and not content (what the program is).

The task force is accountable to Conference participants and will submit its report to them. Participants gave the following charge to the task force:

— Review the Conference proceedings to identify key issues that are not being adequately addressed.
— Define alternatives for forums to discuss priorities for research library preservation activity.
— Define alternative mechanisms for acting upon these priorities.
— Define the scope of community.
— Formulate a draft agenda.
— Set in motion a mechanism for development of a strategic plan.

The task force was appointed and has met once.

Most of the task force members believe that some kind of CNI type of organization attached to ARL would be the best structure for engaging the major players in a planning effort and advancing coordinated collaboration. However, given the economic conditions and the political factors, the task force believes that there would not be enough support for such an organization without a clearer description of what it would do. The Task Force is now in the process of defining the needs that such an organization would meet that cannot be met by existing organizations.

Many ARL libraries are spending millions of dollars on preservation. Thorough investigation and analysis are needed to insure that we are spending those dollars efficiently and for maximum effect. I am grateful that the Library of Congress took the initiative to organize this workshop, and I am pleased that the Preservation Conference in Chicago provided the impetus for it. I hope this roundtable leads to closer collaboration among the few organizations and individuals who are engaged in preservation research.

Martin Runkle has been Director of the University of Chicago Library since 1980. He is past president of the Association of Research Libraries, has served on several boards of library-related organizations, and has presented and published related to the economics of research libraries and to the preservation and bibliographic control of library collections.

PRESERVATION AND MATERIALS SCIENCE

LESLIE E. SMITH, *NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY*

I'm Leslie Smith, materials scientist from the National Institute of Standards and Technology. I'm here today because NIST performs research and provides technical consulting to other federal agencies, including the National Archives and the Library of Congress. I personally have been involved in studies of stability of magnetic tape and the interaction of that experience with materials of infusion and absorption. But I don't want to talk about those technical interests right now.

One of the advantages of being near the end of this long introduction is that many of the specific points that I had in mind have already been made eloquently by other speakers, so I can skip them.

I'd like to make just two observations. First, at the risk of being self-serving, I'd like to point out that materials science is indeed at the heart of many of the matters that we've been discussing here. And in making the educated guesses that Paul Whitmore talked about that apply to conservation strategy, we rely heavily on fundamental data that exists in the literature on both the inherent stability of materials, the interaction of materials with their environment and the interaction of one material with another material in the same system.

It's my observation, coming from outside the preservation community, that the literature in the preservation field is extremely thin on well documented, comprehensive studies of the material characteristics that lie at the foundations of the kinds of questions that we want to ask. And I understand perfectly well the reasons for that. We are driven often by the short-term need to answer a specific question related to an artifact or a set of materials that present a problem. There is an almost overwhelming tendency to make measurements on precisely those materials. As a result, we have a lot of anecdotal evidence, we have a lot of data on samples which cannot be well characterized as being representative of a larger population. And it's therefore difficult for a scientist to say whether the data that has been collected by the preservation community really is in accord with the rest of materials science. We don't know whether the data are in agreement or in conflict because we're not quite sure of the identity of the materials involved.

I think, as a community, we have to find ways to have the larger discipline of materials science to develop fundamental data on materials that are of interest to us. And we also have to pay our dues by at least allocating a share of our research agenda to look at the longer term, more comprehensive data needs of the preservation community. This means balancing the needs and opinions of individual science researchers, but I think it's vital to the community as a whole.

The second observation that I'd like to make is that administrators don't often deal with materials, they deal with systems, and they must consider the systems as an integrated whole. And so I want to echo concerns made before, that we need to develop models of entire systems. These models can be somewhat qualitative in nature.

For example, when one considers issues like digital data storage, you really can't make a one-to-one comparison of technical approaches. The composition of commercial materials involved in most digital formats are not simple or constant with time. For example, we haven't really decided yet what our optical disks are going to be made of. So when one asks the materials science question, how long will they last, it's difficult to even begin because we don't know what materials we're talking about. And is an investment in long-term fundamental studies of materials, that may in fact turn out not to be used, a sensible choice?

There are associated issues of hardware obsolescence. Are we really so concerned about materials stability when the system, the hardware, has a practical? Do investments in materials issues make sense here or should one take advantage of the fact that digital data can, at least in principle, be copied perfectly and take advantage of that attribute?

Therefore, I think what's valuable here are quantitative scientific and engineering models on the behavior of systems. A very simple example of that is the economic trade-offs Scott Bennett was talking about just a few minutes ago. We have a common goal to make information last as long as is economically possible, but we have a whole variety of ways in which we can invest in that. We can provide exquisite environmental controls for buildings in which we house

the materials. We can provide a suitable microenvironment, say, by boxes or by individual rooms that are environmentally controlled. We can provide mass or individual treatments for parts or entire collections, or we can simply transfer the entire collection to other media. And all of these are realistic preservation strategies.

In order to compare one with another or even to evaluate details of each one of these individual strategies, you need an engineering model which contains cost information that allows you to make trade-offs. Beyond that, beyond the goal of providing this information for the administrator who has to make the decision, these are useful tools for guiding the development of technical programs.

I have often felt, without necessarily any hard data, that many of us, as technical professionals, spend time getting exquisite answers to questions which cannot possibly be of any influence on the overall practice of administrators. The effects are simply too small to affect those larger judgements. But in the absence of a quantitative model demonstrating this, it is difficult to make that point with any certainty.

So I feel that these overall models will help set a research agenda as well, as well as providing the answers to the specific questions that administrators face. One is often dismayed by the difficulties of constructing such a model.

Our attempts to do so will be woefully inadequate at first, but it's just that inadequacy that will point to the gaps in the knowledge where we have to put more effort

Further comments on this topic by Leslie Smith can be found in his article entitled "Factors Governing the Long-term Stability of Polyester-based Recording Media" published in *Restaurator* 12: 201-218. Munksgaard, Copenhagen, 1991. The introduction to this article has been printed below.

Information storage on microfilm and magnetic tape offers higher storage density and more rapid access than those of corresponding paper records. These newer media now account for a large fraction of current data and have become important parts of many libraries and archives. In most cases these media are stored under conditions designed for paper-based records. The expected useful lifetimes of these materials under such conditions is long but is not known. During the past decade, the National Archives and Records Administration has sponsored research at the National Institute of Standards and Technology (NIST) aimed at defining the effects of storage environment, developing tests of the condition of the materials and predicting the lifetime of magnetic tape. The objective of this report is to translate the conclusions of this research into practical terms for readers who are less interested in the science of these materials than in strategies for storing and using magnetic tapes. The data supporting the conclusions are contained in previous reports and papers that are referenced.

Dr. Smith, Chief of the Polymers Division of the National Institute of Standards and Technology, most recently has studied the degradation of polyesters and applied the results to estimating the expected lifetime of information storage media, such as microfilm and magnetic tape. Dr. Smith received his Ph.D. from Catholic University in 1969. His field of specialization is polymer absorption of synthetic material surfaces and its relationship to biocompatibility.

PRESERVATION AND THE LARGE RESEARCH LIBRARY

WILLIAM J. STUDER, *OHIO STATE UNIVERSITY LIBRARIES*

I am not a researcher in the field of preservation; rather, I am the director of a large research library (facing major preservation challenges) who developed a special interest in and focus on preservation issues in the early 1980's which led to the establishment of a Preservation Office and program at OSU Libraries headed by a full-time Columbia-educated preservation administrator and which includes a broad array of preservation/conservation capabilities. OSU Libraries received one of the first ten preservation planning grants awarded by the Association of Research Libraries (ARL), and completed its preservation self study in 1986.

I have been a long-time member of the ARL Committee on Preservation of Research Libraries Materials, serving as vice-chair for 1989/90 and chair since 1991. This has been a very active committee, having much to do in setting the ARL preservation agenda. The Committee was responsible for the 1987 ARL fall meeting program (titled: Preservation — A Research Library Priority for the 1990's), at which I delivered a paper ("The Role of the Library Director: Wherefore and Wherewithal"), and sponsored a recent publication, *Preservation Program Models: A Study Project and Report* (1991) which provides context and benchmark guidelines for adequacy of preservation program components. Many other committee activities/projects are of record.

I have also participated in other major preservation meetings and service activities. I delivered a paper titled "Funding Strategies and Public Relations" at the 1991 Roundtable on Mass Deacidification, sponsored jointly by ARL and NDCC and (held in Andover, MA.); I participated in the Preservation Planning Conference (May 1992) sponsored by ARL and the University of Chicago, the main outcome of which was a decision to create a Preservation Planning Task Force to serve under the auspices of the ARL Preservation Committee and charged broadly to review existing North American preservation program activities and to draft an agenda/plan of action for moving forward; I served on the Source Selection Evaluation Board (1991) to review responses to the RFP to provide mass deacidification services to the Library of Congress; and I have been the ARL representative on the National Advisory Council for the Commission on Preservation and Access (1989-1992).

A significant involvement over a two and one-half year period has been membership on the CIC (Big Ten Universities plus the University of Chicago) Task Force on Mass Deacidification whose report was issued in April 1992 (titled: *Mass Deacidification: A Report to the Library Directors*). This extensive study examines the organizational/logistical issues involved with mass deacidification treatment, such as selection, record-keeping, internal staffing, workflow, transportation, quality control, in-house processing costs, contracts, education/training, etc., but also collates results of treatment effectiveness and side effects, as well as touching on toxicology issues. The CIC libraries are determined to move forward as modest, steady consumers, quite possibly in conjunction with other ARL libraries which have expressed interest, thereby building experience and recurring budget resources in a cooperative environment.

I am concerned about all issues relative to preservation, including all non-print media; but am most interested in paper longevity in the context of perfection and use of permanent, alkaline paper, optimal environmental controls, mass deacidification and paper strengthening as these conditions and processes offer on the one hand the promise of greatly reduced future problems and on the other the potential to save the tens of millions of print volumes currently at risk. The longevity of preservation microfilm is obviously a major issue, given the current commitment to mass production. Also, as the inevitable shift to digital/optical information formats accelerates, it is imperative to ensure the preservation of these new media. Early perfection of electronic image technology (i.e., providing a durable product) could surely offer viable alternatives to microfilm and even mass deacidification. How does the reproduced image quality from electronic/digital formats compare with that from microfilm? Are we certain that the specified small tolerances for shifts in climate control have sufficient benefit vis-a-vis the costs incurred? Toxicology issues relative to several preservation processes are ever present.

Perhaps our greatest challenge? To find the will (to develop the momentum) and resources to move forward with preservation on a mass scale. I worry that the price tag will prove near insurmountable in times of protracted retrenchment. In many places and

in many instances it is even now not only (or even so much) a question of additional research, but one of affordability in applying well what we currently know works to the advantage of preservation.

William J. Studer is the Director of Libraries, the Ohio State University Libraries, a position he has held since 1977. From 1973 to 1977 he was Associate Dean of University Libraries, Indiana University. From 1968 to 1973 he was Director of Regional Campus Libraries, Indiana University, and from 1961 to 1965 he worked at the Library of Congress as Special Intern, Reference Librarian and Senior Bibliographer.

PRESERVATION OF LIBRARY MATERIALS FROM A CONSERVATOR'S PERSPECTIVE

PETER WATERS, *LIBRARY OF CONGRESS*

So much has been written and visually dramatized about the deteriorated state of paper-based materials in such serious condition and volume that no one can doubt that a monumental challenge lies ahead of us. The primary focus on preserving deteriorated book collections has centered on brittle books and acidic book material which will some day become brittle. The conventional strategy has been to devlop a two pronged approach; to transfer brittle books to a more stable human-readable form, such as microfilm, and to research mass treatment systems for acidic book collections. According to data produced in 1984, thirty percent of the Library of Congress' Classified and Law collections are brittle (equal to or less than one fold as measured by MIT folding endurance weighted at half a kilogram), and about seventy percent are acidic and not yet brittle.

Given the enormous variety, age range and state of deterioration that exists in these collections, have we over-simplified the means to preserve them? Books are sources of knowledge, inspiration and learning; and they are also three dimensional moving objects designed to human scale, and therefore subject to human use and abuse. The physcial aspects of paper-based materials deterioration may have been overlooked; and it is these aspects together with the manner and frequency of use, that we must study more closely so that future preservation strategies can more closely respond to preservation needs.

Scientific research into collections deterioration is vitally important as we seek to find preservation solutions. It is to be hoped that we can develop new ways to determine the actual condition of our collections and the cariable rates of their deterioration. This may require some new approaches to laboratory testing platforms in which a variety of book conditions can be evaluated within the same testing environment. This would enable us to begin to better understand what is actually occurring on the book shelves and in storage systems.

We need to learn more about the influence of micro and macro envirnments on the rate of deterioration. One of the major reasons why paper-based materials at LC apparently deteriorated at an exponential rate is because, up until the mid-sixties, we did not have control over the macro environment. Some have speculated that the conditions that existed at LC up to the mid-1960s caused collections to undergo a natural form of aging. We have better control now, and as a result the rate of deterioration in which these collections are deteriorating must be slowed. But how do we prove this from a scientific point of view? Perhaps the emergence of some new technology for monitoring individual volumes and groups of books on the shelves will help us in our determination of appropriate responses.

Peter Waters was appointed Conservation Officer at the Library of Congress (LC) in 1971. In 1952, he received his Masters Degree and Silver Medal special achievement award from the Royal College of Art (RCA) in London, where he had specialized in bookbinding, graphic design, lettering and typography. Between 1952 and 1971, he was visiting lecturer at the Royal College of Art, and also joined his RCA professor, Roger Powell, in partnership in fine binding, book and document conservation until 1971.

During his forty years in library conservation, he has held many consultancy positions dealing with fire-and-water damage and collections preservation, among them for the Biblioteca Nazionale, Florence, Italy, the Gulbenkian Museum Library, Lisbon, Portugal, the United States Archivist, the Los Angeles Central Public Library and the Library of the Russian Academy of Sciences, St. Petersburg. From 1967 to 1969 he was Co-director of a research program at Imperial College of Sciences, London, to investigate library preservation problems resulting from the Florence flood of 1966.

Waters is a Fellow of both IIC and AIC and has served on various committees, including the Executive Committee of the Preservation Advisory Committee to the National Archives and Records Center, as the LC Liaison Representative to the Committee on Preservation of Historical Records, the National Materials Advisory Board, and the Commission on Engineering and Technical Systems, National Research Council. He has recently risen to the position of Preservation Strategic Planning Officer at the Library of Congress.

SOME HAPPENINGS ON THE WAY TO THE DEVELOPMENT OF PERMANENT RECORD MATERIALS

WILLIAM K. WILSON, *NATIONAL ARCHIVES AND RECORDS ADMINISTRATION*

As this manuscript was written in five days, the literature survey consists of what was in my home library, and no claim is made for completeness or total accuracy. However, it is hoped that the information will be useful in putting the development of permanent record materials in perspective.

One of the problems in the records area is that the demand for permanent record materials does not justify the necessary expenditure to make them. Several years ago at a professional meeting a papermaker was extolling the virtues of alkaline paper. He listed 14 advantages, and the 14th was permanence. He said, "Alkaline papers are far more permanent than acid papers, but don't try to sell your paper on the basis of permanence — no one is interested."

There are many ways a historical paper of this nature could be written, and this one is arranged by time periods. The progress in earlier times may seem somewhat juvenile, but we must remember that the invention of the wheel, which we take for granted, was a giant step forward.

BEFORE 1900

We certainly should take a bow to Emil Fischer, the nobel prize winner who determined the structures of the sugars, especially glucose. This work was required as a basis on which cellulose chemistry could build. It is questionable whether Fischer had any idea at the time of the importance of his work to cellulose chemistry — in the twenties the greats were arguing violently over the existence of polymers.

We also must list Arrhenius in this time frame. His classic paper, published in 1889 **(1)**, discussed for 23 pages the inversion of raw sugar by acids, and on one page he gives his famous formula showing the relationship between reaction rate, temperature and activation energy. Although he is known the world over for his famous "Arrhenius Plots," it is ironical that not a single plot appears on any of the 23 pages. It should be noted in passing that Arrhenius developed the theory of ionization for his doctoral thesis. His major professor and his examining committee were so unimpressed that he just barely got his degree. The examining committee is forgotten, but Arrhenius is known to every chemist the world over.

1900-1930

Smith **(2)** gives an excellent account of the history of records deterioration, especially before 1900, and Wilson **(3)** provides a history of records research at the National Bureau of Standards. Thomas **(4)** describes the history of alkaline papermaking up to about 1969. Kantrowitz, et al **(5)** provided a bibliography on permanence and durability from 1885 to 1939, and Luner **(6)** published an excellent article on paper permanence covering the literature up to 1969.

The good news in 1901, although practically no one knew it, was making paper with an alkaline filler. This was the handiwork of Edwin Sutermeister **(4)**. Although he knew what he was doing, the real reason for doing it was that his boss told him to do something about the hugh pile of by-product calcium carbonate in the back yard of the mill. Sutermeister set aside some samples for storage and, as of about 10 years ago, these samples still were in good shape.

In 1925 Gosta Hall of the Royal Technical University of Sweden spent a month in the Paper Section at the National Bureau of Standards (NBS). Having just completed a project in Sweden on the permanence of paper, he was of great assistance to NBS scientists, and he influenced the direction of records research for many years. Dr. Hall showed that alum was bad for stability of paper. Nothing new, but he provided quantitative data. He developed the 100° C dry oven aging test, and he developed a method for determining the acidity of paper. These tests are TAPPI standards today.

In the late twenties a research program was initiated in the NBS Paper Section on stability of records, and this program was active until WW II. It was initiated by the American Library Association, the Carnegie Foundation, and the National Research Council. In the early thirties the National Archives joined the list of sponsors.

1930-1950

The above program was very extensive for the time, and the following results were obtained:

1) Papers containing rosin-alum could be very stable toward accelerated aging if no excess alum were used. An excess of alum produced an unstable paper.

2) Papers made with a calcium carbonate filler were very stable, but no more stable than the above rosin-sized papers with a minimum of alum.

3) Two programs were started on comparison of accelerated aging with natural aging. These programs would later show that aging for three days at 100° C in a dry oven correlated fairly well with natural aging. However, it was obvious that the prediction of stability by accelerated aging was not an exact science. They also showed that rosin sized papers were very stable if not quite enough alum was added to react with the rosin, and that papers containing a calcium carbonate filler were very stable.

4) The deleterious effects of sulfur dioxide was demonstrated, and a procedure was developed for removing sulfur dioxide from library air.

5) t was shown (in my opinion, not beyond a reasonable doubt) that microfilm could be used safely for permanent records.

6) It was demonstrated that cellulose acetate film could be used for the lamination of documents.

7) From a study of the effect of light on paper, Launder **(7)** showed that: a) Paper is bleached by light, if irradiated without heating. b) The principal reaction(s) is photo-oxidation—oxygen is necessary for the reaction to occur. c) A post-irradiation effect occurs in which the paper is bleached during irradiation, and darkens in dark storage. Today this would be discussed in terms of trapped free radicals. d) Newsprint is bleached by light in the absence of oxygen. e) Newsprint is greatly stabilized against photo-oxidation by impregnation with sodium bicarbonate.

Hanson **(8)**, while a graduate student at the Institute of Paper Chemistry, examined a book dated 1576 in which the signatures were printed on different kinds of paper. They varied from discolored and weak to white and strong. It was found that the white, strong sheets contained about two percent calcium carbonate.

In the late thirties, load-elongation was performed with a balance arrangement to measure load and with an optical set-up to measure elongation. Ten years later, with the spurt in electronic instrumentation motivated by the war, load-elongation was performed with a recording load-elongation instrument. This was real progress, for elongation and tensile energy absorption are important parameters in the aging of paper.

A specialized preservation task of the forties was the preparation of the Constitution, Declaration of Independence and Bill of Rights for storage and display. The NBS and Libby-Owens Ford cooperated with the Library of Congress on this project. In 1952 the display was moved to National Archives.

One of the most important happenings of this period was the appearance of William J. Barrow with his lamination-deacidification procedure. Although the practice started out with lamination, the heat of the laminator darkened the more acidic papers. So the invention of deacidification was an absolute necessity. Although Mr. Barrow had little technical training, he was not afraid to ask questions. He distributed his machine and services in this country and Europe, and was one of the substantial contributors to the field of preservation. He will be mentioned later.

1950-1970

These two decades saw a real awakening in records research, and several laboratories were created. Previously, records institutions did not have in-house research facilities, but contracted research to scientific institutions. This period saw the creation of the research laboratory of the Library of Congress, directed by Frazer Poole, the research center at Carnegie Mellon University, headed by Robert Feller, and the Barrow Research Laboratory in collaboration with the Virginia State Library.

The report commissioned by the Library of Congress and prepared by the Southwest Research Institute on Preservation and Storage of Sound Recordings (1959) was a substantial contribution **(9)**. Much of the information is still useful, but the important aspect of the report is that it calls for cooperation between government and industry to secure the best in recordings: "For the future, it is desirable to have more stable media of longer life and less dependence on expensive storage environments and techniques. The present state of knowledge would permit manufacture of sound recordings of several times the potential life of currently used media." The best way to handle this situation is through a standards organization, such as ASTM.

This time period saw the beginning of the wholesale use of Arrhenius plots in aging studies. Steiger

(10) described the application of the Arrhenius equation to 1) a study of the aging of nylon, 2) the effectiveness of antistatic agents, 3) bath stability of a thermosetting resin, and 4) speed of curing of a finish for nylon.

Gray **(11)** used Arrhenius plots in a study of the applicability of TAPPI Standard 453 "Effect of Dry Heat on Properties of Paper to predicting the relative stability of papers". Wilson **(12, 13)** used the Arrhenius approach in evaluating the stability of cellulose acetate films.

This period saw the beginnings of the use of other aging conditions for paper besides dry heat. Wilson **(14, 15)** used 90° C, 50% relative humidity in the aging of several papers. The Library of Congress also used 90° C, 50% relative humidity.

In 1954 the NBS was commissioned by the National Archives, the Library of Congress, the Army Map Service and the Virginia State Library to study the procedures used in the lamination of documents, to write specifications for a lamination film of cellulose acetate, and, if time permitted, to study deacidification. Specifications were written, the process of lamination was shown to be feasible on a long term basis if proper care was taken, and deacidification was given a clean bill of health (on the basis of very scanty data). Lamination has been discontinued by many institutions.

In 1966 the National Archives contracted with the Paper Section of NBS to develop specifications for permanent record papers. This project was to last more than 10 years. Part of the work was contracted to the New York State College of Forestry, and it was there that Cardwell **(16)** found that the cycling of temperature and relative humidity was more damaging to paper than a constant temperature and relative humidity.

During this work, the following was acommplished:

1) Four specifications for permanent record paper were developed and became ASTM standards Bond and ledger paper, Manifold paper, File folders, and Copies from office copying machines.
2) Aluminum on the cellulose carboxyls was identified as a contributor to degradation.
3) Thermal analysis of modified cellulose, and of various papers of varying degrees of stability, showed that thermal analysis probably could be used as a quick measure of stability. Unfortunately, time did not permit bringing this to a successful conclusion.

During this period spots, or blemishes, were discovered on microfilm, and it is uncertain whether the problem has been solved even today. Blemishes usually occur in the first few meters of a film roll, although they have been observed far into the roll. The image seldom is obliterated. The current thinking is that only film with polyester base should be used. It should be well washed after development, but still contain a trace of thiosulfate, a sulfite treatment should be part of the processing, and it should be stored at 21° C and 20 - 30 % relative humidity.

During this time the Barrow Research Laboratory 1) improved their deacidification procedure, 2) studied the condition of paper in books from 1507 to 1949, 3) developed specifications for permanent book paper, and 4) studied the use of polyvinylacetate adhesives in library bookbinding. Items 3 and 4 were well done and timely, but were not coordinated through a standards organization, so their effectiveness was severely limited.

In the late fifties, James L. Gear developed and put to use at the National Archives, the magnesium bicarbonate method of deacidification.

1970 - PRESENT

If the period 1950 - 1970 was the awakening of records research, the time after 1970 was the explosion. The National Archives continued, to intermittently, contract research with NBS, but created its own laboratory in 1976. The Smithsonian Institution created the Conservation Analytical Laboratory. The Preservation Research and Testing Office at the Library of Congress and the Carnegie Mellon Institute developed substantial research programs, and the Getty Conservation Institute in Marina del Rey, CA developed a research program for museums and archives.

Laboratories abroad include the Canadian Conservation Institute (Helen Burgess) in Ottawa, Canada, the National Archives of Canada (Klaus Hendriks) in Ottawa, the Department of Conservation of the British Museum (Vincent Daniels) in London, the Department of Paper Science (Derrick Priest) at the University of Manchester, Institute of Science and Technology, England, Centre de Recherches sur la Conservation des Documents Graphiques (Françoise Flieder) in Paris, Istituto di Patologia del Libro (L. Santucci), Rome. And finally, Riksarkivet, the national archives

of Sweden (Ingmar Frojd, coordinator) is carrying out some important work on the aging of paper and the effect of air pollutants on paper.

Graminski **(17)** and Du Plooy **(18)** systematically studied the degradation of paper at various temperatures and relative humidity values. For the first time, one could look at the broad picture of the effects of temperature and relative humidity on the degradation of paper. Paper degrades about twice as fast at 50 % relative humidity as at 25 %.

In order to assess the effect of change in temperature on degradation, one must have an idea of the activation energy of the degradation reaction. Erhardt **(19)** has discussed this; the higher the activation energy, the more sensitive the reaction is to changes in temperature.

Several new initiatives on deacidification have appeared since 1970. Smith developed a magnesium, non-aqueous process, which also includes a spray deacidification technique. This process has been in operation at the National Archives of Canada for several years. Lithco, a subsidiary of FMC, also uses a non-aqueous magnesium coordination compound which strengthens as well as deacidifies. The British Library is developing a procedure for deacidifying and then strengthening by polymerizing acrylic monomers into the paper with gamma radiation. The Library of Congress worked for several years on a vapor phase process using diethyl zinc, and the process is in the pilot plant stage at Akzo Chemicals.

In September, 1990, the Library issued a Request for Proposals for deacidification. None of the vendors met all of the Library's requirements, but Akzo met all requirements except odor and appearance. Akzo is attempting, through development contracts, to correct the situation (*Abbey Newsletter*, April 1992). Harvard University has contracted with Akzo to treat a portion of its collections, "partly as a way to make sure the suppliers will still be there when they are needed in the future" (*Abbey Newsletter*, February, 1992).

So the jury is still out on mass deacidification. Resolving the dilemma will be costly, for the problems are in the pilot plant stage, and beyond. However, the stakes are high, and the arresting of deterioration of millions of books is the prize. The alternative is the ultimate loss of millions of books and other documents to degradation.

Hindsight is 20-20. Nothing new. But the cost to society of deteriorating records, and the effort to correct this deterioration, probably has been far more costly than using stable paper in the first place. This is not meant to point the finger at anyone. To have changed the situation would have taken planning of a type that does not exist in many modern societies.

A problem that has surfaced in the last couple of years is the attempt of makers of high yield pulp, which contains lignin, to include these pulps in the stock of papers meant for permanent records. Studies have shown that papers containing high yield pulps and a filler of calcium carbonate, except for discoloration, are stable toward accelerated aging. It will take a substantial research program to resolve this problem.

One issue of *Restaurator*, Vol. 12, No. 4, 1991, was devoted to the storage of records media other than paper. Constance McCabe discussed the problems of preserving and using photographic materials, Leslie Smith covered the factors governing the long-term stability of polyester-based recording media, and Helmut Bansa's presentation had a very prophetic title: "The New Media: Means for Better Preservation or Special Preservation Problems?" It is obvious that each new records medium brings its own set of advantages — and problems. The maker of records on stone tablets probably quipped sarcastically, "The new papyrus won't last."

McCabe and Smith, to greatly simplify their presentations, say to store the records material at low temperature and low relative humidity. Of course one must contend with people problems, limitations of air-conditioning equipment and lack of resources. In addition to excellent suggestions for storage and handling, Bansa makes the point: "The preservation of the hardware and software that is necessary to access optical databases produced physically in our time might become the main problem."

Standards are one important end point of research. The American National Standards Institute (ANSI) has promulgated standards for permanent paper, and for permanent and durable library cards. In the photographic area, several standards are available for storage of various types of processed media. ASTM has issued four standards for permanent record paper, and a guide for permanent book paper is in the final stages of development.

Predictions for the future have been notoriously inaccurate, even when made by experts, but here are two categories to ponder:

What should happen? A systematic study should be made of why various record materials degrade, and how they can be made stable. ASTM and ANSI standards should be written to cover this information. This should include storage conditions.

What will happen? Most studies will be made to solve specific problems, and not on the basis of an overall plan. This usually is the way most progress is made, but it takes longer to fit the data into the whole picture.

REFERENCES

1. Arrhenius, Svante. "Über die Reaktionsgeschwindigkeit bei der Inversion von Rohzucker durch Säuren." *Zeitschrift für Physikalische Chemie* 226-248 (1889).

2. Smith, Richard D. "Paper Impermanence: pH and Storage Conditions." *Library Quarterly* 39 (2): 153-195 (1969).

3. Wilson, William K. and Parks, Edwin J. "Historical Survey of Research at the National Bureau of Standards on Materials for Archival Records." *Restaurator* 5 (3/4): 191-241 (1983).

4. Thomas, Joseph J. "Alkaline Printing Papers." *Library Quarterly* 40 (1): 99-107 (Jan. 1970).

5. Kantrowitz, Morris S., Spencer, Ernest W. and Simmons, Robert H. *Permanence and durability of Paper: Annotated bibliography of the Technical Literature from 1885 A.D. to 1939 A.D.* Washington: U.S. Government Printing Office, 1940.

6. Luner, Philip. "Paper Permanence." *Tappi Journal* 52 (5): 796-805 (May 1969).

7. Launer, Herbert F. and Wilson, William K. "Photochemical Stability of Papers." *Journal of Research of the National Bureau of Science* 30 (1): 55-74 (Jan. 1943).

8. Hanson, Fred S., "Resistance of Paper to Natural Aging." *Paper Industry and Paper World* 20 (11): 1157-1163 (Feb. 1939).

9. Pickett, Andrew G. and Lemcoe, Meyer M. *Preservation and Storage of Sound Recordings.* Washington: Library of Congress, 1959.

10. Steiger, Fred H. "The Arrhenius Equation in Accelerated Aging Studies." *American Dyestuff Reporter* 47 (9) 287-290 (May 5, 1958).

11. Gray, Glen G. "An Accelerated-Aging Study Comparing Kinetic Rates vs. TAPPI Standard 453." *Tappi Journal* 52 (2): 325-334 (Feb. 1969).

12. Wilson, William K. and Forshee, B.W. "Degradation of Cellulose Acetate Films." *SPE Journal* 15: 146 (1959).

13. Wilson, William K. and Forshee, B.W. *Preservation of Documents by Lamination.* (National Bureau of Standards Monograph, 5) Washington: U.S. Government Printing Office, 1959.

14. Wilson, William K. and Hebert, Robert L. "Evaluation of the Stability of Record Papers." *Tappi Journal* 52 (8): 1523-1529 (Aug. 1969).

15. Wilson, William K. and Hebert, Raymond L. "Evaluation of the Stability of Manifold Papers." *Tappi Journal* 55 (4): 1103-1107 (July 1972).

16. Cardwell, Robert D. *Aging of Paper.* Ph.D. dissertation, New York State College of Forestry, Syracuse, N.Y., 1973, p. A2-A4.

17. Graminski, E.L. "The Effects of Temperature and Moisture on the Accelerated Aging of Paper." In *Durability of macromolecular Materials.* edited by R.K. Eby. (ACS Symposium Series, no.95) Washington, American Chemical Society, 1979.

18. Du Plooy, Adriaan B.J. "Influence of Moisture Content and Temperature on the Aging of Paper." *APPITA Journal* 34 (4) (Jan. 1981).

19. Erhardt, David. "Relationship of Reaction Rates to Temperature." *Abbey Newsletter* 13 (3): 38-39 (June 1989).

William K. Wilson earned his M.S. in chemistry from West Virginia University. He has thirty-eight years of experience in paper research at the National Bureau of Standards (National Institute of Standards and Technology). He has been a guest worker at the National Archives and Records Administration. Most of his publications are on 1) the effect of light on paper, 2) the stability of cellulose acetate films, 3) accelerated aging of paper under various conditions, and 4) work with ASTM on the development of guidelines and specifications for paper for permanent records.

SESSION II

ELECTRONIC IMAGE MANAGEMENT

THE DILEMMA — PRESERVATION VERSUS ACCESS

THOMAS C. BAGG, *NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY*

INTRODUCTION

The subject of this Round Table is to explore techniques for the preservation of recorded information. As pointed out by the keynote speaker, this is only a part of the overall preservation program, but is more than enough to fill these two days of discussions.

Preservation has been on the minds of people since the first drawings on cave walls. As you know even the Pharaohs were concerned. So over the years a number of solutions have been proposed. One which came up frequently at meetings like this, and is technically sound, was to store all these great works written in books, journals or microfilmed in a cold vault dug in the ice cap at one of the poles. While this is a great solution for preservation, there are some people who occasionally want to use these materials. I have been told this solution will not work because library pages do not want to wear parkas to retrieve and shelve the needed items.

This raises the dilemma — preservation versus access. Even with today's technology the best ways to meet these needs seem incompatible.

How can we combine the two needs, preservation and access? I wish I could tell you. However, one of my assignments for today was to raise some questions or at least raise some of the issues.

CHARACTERIZATION OF DATA

I have been told by several archivists that probably less than 2% of all the things written are of permanent, or even long term, value. That sounds like a small amount, but to most of you in this room even that represents a vast quantity of information. Our host for this meeting, the Library of Congress, has a number of buildings around here that are filled with this type of information.

Some 25 years ago, when I first got deeply involved with preservation the consensus of people who managed large collections of, what was thought to be, valuable material was that:

— 50% of the material in the collection would never be looked at in its lifetime;
— 40% might be looked at 5 or 6 times in its lifetime;
— 8% could be identified for low use, but most of it would come from any place in the collection;
— 2% could be identified as potential high use materials.

While the actual figures are immaterial, they identify four major categories of materials present in any large collection which has been designated as having potential permanent value.

Let me begin by talking about the bulk of such a collection, the 90% which is never or seldom looked at. This is where the preservationist must play God. Although they would by nature want to save everything, time and money unfortunately dictate priorities. How much time or money are available for preservation and access?

Now, before I go any further, let me make it quite clear that access tools, or retrieval hooks, are essential to any size collection regardless of the media: paper, stone, tablers, microfilm, electronic records or whatever may come next. For this talk I will refer to these retrieval tools as indices. This is an overall term for all the access tools, catalogs, key words and even full text searching. The better or more complete the index, the faster and more complete a search will be in identifying and retrieving the needed items.

However, nothing is free. Indexing takes time and it costs money, whether it is done manually or automatically. So how much should be spent on the infrequently accessed items? There must be judicial trade offs, in access methods as well as in preservation. Unfortunately most of the world's literature, technical and otherwise, has been printed originally on paper, most of which has a self-destruct mechanism built into it. I should add that through the efforts of some of the people in this room, this may be changing with the availability of acid-free, buffered papers for publishing and hopefully for general use.

Today we are faced mostly with preserving information in existing documents. However, we must begin to plan for the preservation of information being generated now and in the future.

OPTIONS OF PRESERVATION

Disregarding at present the indexing issues, what are the current options for preserving the approximately 90% of the information believed valuable which may be on a degrading media?

Essentially, there are three choices. They are copying to:

Non-degrading (stable) paper
Microfilm
Digital media

STABLE PAPER

Using stable papers (acid-free and buffered) may be a realistic and user friendly solution. If many pages must be read, paper is preferred by most users. In addition the life expectancy, when properly stored, is predicted to be 500 years or more. However, making paper copies are labor intensive, particularly with old or bound documents. Furthermore paper is bulky, therefore costly to store and retrieve. The Cornell project described by Anne Kenney is a good example of an effort to combine preservation and access.

MICROFILM

Preserving data on polyester-based microfilms may be a little less expensive than using paper. In addition to cost, film has a number of other advantages over paper. A very significant one is the space required for the collection, which may be reduced by a factor of 12 to 50. Duplicates can be made and distributed relatively inexpensively, and, if adequately indexed, the needed frames can be retrieved and copied much more easily than pages from a similarly sized paper file. The life expectancy of microfilm, when properly stored is estimated to be at least 500 years. The Yale conversion project reported by Paul Conway is a good example of an effort to combine preservation and access.

DIGITAL MEDIA

With the almost daily changes in digital systems, mostly to achieve higher densities and faster access times, these systems have a short life expectancy. Due to this, it is difficult at this time to recommend digital systems for use in preservation. I base this not only upon my own observations, but primarily on the study titled "Preservation of Historical Records".[1] Although this report is six years old, I do not believe digitial technology has become more stable in that time.

One of the reasons for this instability is a lack of standards. I recommend that you read the articles in the September 1992 issue of the *Journal of the American Society for Information Science*, particularly Richard Cox's paper titled "The American Archival Profession and Information Technology Standards".

One of many important papers he cited contains the following:

Frederick J. Stielow noted that "one must recognize that the financial concerns of the computer industry do not necessarily serve the preservation of records. The automatic industry has vested interests in producing new and proprietary products with little continuity or thought of preservation...the reverse of an archival perspective... The results are technology-driven selections fraught with rapid obsolescence, compatibility problems, million dollar mistakes, and vaporware."

Since I think you should all read the entire article, I will not try to summarize it here. Some of my computer associates concede that digital technology has not yet stabilized, but claim that it will someday. Maybe so, but I doubt in my life time.

This morning Dr. Smith made it clear that preservation in a digital form is not a material science problem but a software and hardware problem. He questioned the validity of an accelerated aging test on ever changing software.

I am not concerned about developing optical media with an acceptable life expectancy. There is some question about the life expectancy of media used today, but the optical disks made 30 years ago were made of photographic materials which are capable of having an acceptable life expectancy. Other materials are available that appear to be capable of the life expectancy required.

Magnetic media still does not have the stability required for preservation, but that does not preclude the development of a suitable media. However, its erasable/rewritable feature may prevent it from ever meeting all of the requirements of a preservation media. It is true that some very large information or data collections have been stored on open reel magnetic tapes for at least 40 years. Because of the sizes

of these files and the value of the information in them, the retrieval devices are being maintained and new tape is inexpensive so the files can be recopied periodically. How long this will be economical is of great concern to the custodians of such information banks. Look at what happened to the enormous punch-card files. Right now I am trying to find a card-reader for someone who has some research data on punched cards to which he would like to have access.

The real concern of preservationists about digital systems is the lack of stability of the hardware and software. It appears, as Cox pointed out, the name of the computer game is change for faster and higher density systems. This may be good for processing, but hardly for preservation. Data formats are always changing, which in turn impacts the hardware design. All the information is in computer codes so not only must the information be kept, but most importantly, the encoding schemes. And when images are to be stored, compression algorithms are used which are forever being improved and made more complex.

There are some standards and others are being developed, but today they are being revised or replaced by something new. Therefore, the preservation of important information in digital form does not appear as a suitable means at this time.

ACCESS OF DATA

While the thrust of the following discussion is centered on digital files stored on digital media the level of search tools or indices required are the same no matter what storage media is selected.

One of the great advantages of a digital file in machine codes as opposed to images, is the ability to manipulate the data and create search strategies. Today's world would be in terrible shape as far as records keeping was concerned if we did not have such automated digital systems. Fortunately the need for keeping most of these types of records for any length of time is low since they are of a transient nature.

However, a very serious situation is developing, that is how to preserve those records of permanent value, which are created, used and maintained only in an electronic format? These are the records of the present and foreseeable furture. Although this subject is of great interset to everyone here, it is my understanding that it is only one of many issues in the scope of this Round Table.

There is one aspect of machine readable information that is essential to preservation, that is, what I am calling the indices. If the collection is properly indexed, required items can be quickly identified for retrieval. The level or depth of indexing, which is time consuming to create, is determined by trade offs. In active files, one can spend more time indexing to save time of retrieval. In files with very low activity, such as the 90% I discussed earlier, indexing is required to locate items, but a longer retrieval time may be acceptable when total costs of both indexing and retrieval time are included.

Some highly used collections, such as those required by lawyers, have been converted to a machine readable format so full text searching can be done very quickly. But how much can be invested in indexing many items which may seldom, if ever, be requested?

It should be emphasized that this refers to machine readable codes, not images. Eventually images may be searched economically, but today it can be time consuming since most images are compressed. To be converted into machince readable format for searching requires decompression and character recognition with verification.

Indices are very valuable and should be backed-up. If the data is of long term value, the indices could be computer output microfilmed or printed to paper.

Before I get to my last points, I must emphasize that no matter what media is chosen for your preservation program, insist that the recorded images be of the best quality. For paper, this means good contrast between the information and the paper. For microfilm, have crisp images with sufficient resolution to capture the details. I realize this takes more memory space even when lossless compression is used. In any system, if all of the original information is not captured, reading will be difficult and without a good quality image, it may not be machine processable.

One project of interest is the conversion of microimages of printed text to machine readable codes by OCR techniques. This relates to providing full text access to selected portions of microfilm prepared for preservation.

Optical character recognition from print on paper had been evolving for over 30 years. Today there are some very powerful, and economic systems which can read many fonts.

Recognizing characters from microimages has been successfully demonstrated several times over the past 20 years, with the most versatile system being the Graphics V built by Informational International Incorporated. It was good, but expensive, costing several millions of dollars. (It included a mini-computer).

In 1984, a task group chosen by the then archivist Dr. Warner to look at methods of preserving the machine readable information the Archives had collected on magnetic tapes, wrote a "White Paper." In summary, the report recommended that the machine readable information be converted into a human readable format and stored as images on microfilm, as "the simplest, most effective, and lowest risk approach".

As usual, there were little or no Federal funds to support an investigation. Discussions were held with the major microfilm and OCR equipment manufacturors and the integrators. They all thought it would be a great program but they were too busy with their own projects to give this one any time.

Eventually, the National Institute of Standards and Technology (at the time the National Bureau of Standards) received a little funding to have a breadboard microfiche-OCR reader assembled from off-the-shelf components. It was a very crude device but it demonstrated the feasibility. In addition, the system highlighted a number of problems showing that reading film images was not as straight forward as reading paper images.

Since no more Federal funding was available, several private sector groups have done some development work in this area. Now a number of people say they can do it, but only one, to my knowledge, has successfully converted any quantity of real life COM microfilm images which contained many unanticipated problems.

Within a year or so I expect systems or services to be economically available which will permit converting selected portions of microfilmed preservation files to a machine readable form for either full text searching or to be automatically indexed.

With the advancement of neutal network systems, I am sure that within a few years most of the high quality microfilmed images could be converted, as required, to machine codes. I also see the possibility of neural network developments to resurrect a 1960's project which proposed full text searching of human readable paages by using holographic storage techniques to spot or copy selected pages or frames. If microimages were used, they could be searched by a device like the Rapid Selector which transported the film at 20 feet/second and copied the selected frames on the fly.

Before I stop talking let me show you an example of information compaction.

Figure 1 shows a 120 mm diameter CD - which I am sure you are all familiar with. I am told it can hold over 550 million bytes, the equivalent of 1500-8 1/2 " x 11" typeset pages when compressed. This is not necessarily the size disk one would use for preservation, but it is touted as a great optical format and has approximately the same information packing density per square as the larger sized disks.

In addition, Figure 1 shows 1245 pages in human readable form reduced 250 times in a 33 mm square of microfilm. That is 6 1/2 times less space when compared to the CD.

This film has been kept in my laboratory in a manilla envelope for over 30 years and is just as legible now as it was when given to me.

In the information the producer sent with it, they said ".....all of the millions of books now stored on the 270 miles of shelving in the Library of Congress could be reproduced on such slides and then could be stored easily in six standard filing cabinets."

In conclusion, at the present time it seems that documents believed to have permanent value must have some type of index and be preserved in human readable form on either acid-free/buffered papers or microfilm prepared in accordance with the appropriate standards. That portion of the collection which can be identified as having moderate to high use, should also be stored in digital form, preferably in machine readable codes to facilitate access. When functional standards are developed for digital systems, this could change.

I hope I have set the stage for an animated discussion on "The Dilemma".

ENDNOTE

[1]Prepared by the Committee on Preservation of Historical Records under the auspices of the National Research Council and the National Archives and Records Administration.

Thomas Bagg graduated from Lafayette College with a degree in Physics and continued in graduate school until 1941. At that time he joined the National Defense Research Committee to work on the proximity fuze. That project was transferred to the National Bureau of Standards where he has remained, working on a variety of assignments.

In 1956 he was asked by the Computer Division to investigate the use of photo-optical techniques for mass memory systems. This included using optical systems based on photography, microfilm, optical disks, drums etc. To design viable systems, an understanding of the image quality, durability, preservation standards, etc., became essential. In recent years most of his effort has been spent on national and international standards.

He is a member of several professional societies and a Fellow of the National Microfilm Association, now the Association for Information and Image Management.

PRESERVATION R & D ACTIVITIES AT THE NATIONAL AGRICULTURAL LIBRARY

GARY K. MCCONE, *NATIONAL AGRICULTURAL LIBRARY*

The National Agricultural Library has been exploring the capabilities of optical technology to enhance preservation and access techniques for nearly ten years. During that time NAL has evaluated laser videodiscs, WORM discs, CD-ROMs, and Internet. We have evaluated analog images, digital images, rekeying full text, scanning page images, optical character recognition, and scanning microfilm. We have also listened to the well-reasoned but conflicting arguments of various pundits who have chastened us for our spelling of disc/disk, laserdisc/laserdisk/laser disk, videodisc/videodisk, etc.

In each of these projects NAL has joined with other agencies or universities who share our belief that optical technology holds too much potential for preservation of our valuable materials to be ignored or dismissed as a passing fad.

PORK INDUSTRY HANDBOOK

In 1984 NAL initiated a project in which the full text of the *Pork Industry Handbook* was placed on a 12-inch laserdisc. The *Pork Industry Handbook* is a major reference work for those involved in raising and selling swine. The textual portion of the publication was rekeyed from the printed version, while analog images of the graphic portion (pictures, drawings and charts) of the publication were created on videotape. We also loaded 150,000 bibliographic records from AGRICOLA onto the disc as there was plenty of room.

The retrieval system used BRS/Search and required a monochrome computer monitor to view the ASCII text, and an adjacent video monitor to display the associated analog images.

LASER II

Following on the heels of the *Pork Industry Handbook* laserdisc and using the same storage medium and retrieval package, this disc contains the full text of twelve different publications ranging from *The Woodland Handbook* to *The 1986 Fact Book of U.S. Agriculture*. Assuming that rekeying text was not the most efficient method to transfer documents to disc, we tried scanning and optical character recognition, converting existing word processing files, and writing programs to convert offset-publishing tapes.

FOREST SERVICE PHOTOGRAPH LASERDISC

Also begun in 1985, this 12-inch laserdisc contains over 34,000 black and white photos selected from the browsing file of the Forest Service historical photograph collection housed at the National Agricultural Library. The disc also contains 500 color slides, 55 color botanical illustrations, 175 maps, and a 60-second Smokey Bear public service announcement.

These analog images were filmed with a single-frame camera using 35 mm motion picture film. The corresponding bibliographic database was built on a magnetic hard drive using C-Quest Photo Database Software. The location code on the disk could not be added to the bibliographic records until the final disc was manufactured.

USDA/OFFICE OF PUBLIC AFFAIRS WORM DISC

After evaluating the Forest Service Photo Disc, USDA officials approved a project to be managed by NAL which would replace the outmoded, manual USDA photo reference system for current and historical photographs with its scattered local photo files. WORM technology coupled with C-Quest software was to control and display requested images for selection. (Fig. 1)

Photographs selected by USDA were recorded as still frames on an 8-inch WORM disc using a high-resolution 3CCD (Charge Coupled Device) camera. During the project, copies of the WORM were made

every two weeks and sent out to five remote offices for their use. The previous WORMs were returned to NAL to have the next two-weeks' photos added. The bibliographic database was also updated on magnetic Bernoulli Box drives at the same time.

At the completion of the project, the images from two WORMs were combined onto a single 12-inch laserdisc with corresponding magnetic bibliographic database.

NATIONAL AGRICULTURAL TEXT DIGITIZING PROJECT (NATDP)

In 1987, the National Agricultural Library and 44 land-grant university libraries joined in a project to evaluate document scanning, optical character recognition, and using CD-ROM as a storage and dissemination medium to facilitate preservation and access.

The capture system is built around a NEC 286 microcomputer, a Ricoh 300 dpi scanner, a Calera OCR system, a 5 1/4-inch WORM drive, and a LaserView high-resolution monitor. Several different retrieval packages were evaluated during the project, with Windows Personal Librarian being selected for our future CD-ROMs. (Fig. 2)

We started the project by including full page images for each page in a publication and also running the images through OCR for creation of an ASCII file of the full text which could be searched word-by-word. As good as the OCR accuracy is, and we were averaging near 95% accuracy, the cost involved in editing the file to 100% accuracy proved prohibitive. This became even worse as we began scanning older materials which were not of as high physical quality and our accuracy rate dropped to 80%-90%. For our more recent discs, we have been omitting the OCR step, and are relying on searching the bibliographic record (with or without abstract) to access the appropriate documents.

Thus far we have produced or assisted with CD-ROMs in the following areas: Aquaculture; Food, Agriculture and Science; Acid Rain; Agent Orange; Food Irradiation; Extension Sampler; and Agronomy. We are currently working on a disc on water quality and another containing a portion of the papers of George Washington Carver which were scanned from microfilm provided by Tuskegee University.

Our most recent CD-ROM contains page images for volumes 1-16 (1907-1924) of *Agronomy Journal*, the main research journal of the American Society of Agronomy.

IMAGE TRANSMISSION PROJECT

For the past three years the National Agricultural Library has been cooperating with North Carolina State University Libraries and eight other land-grant university libraries using image file transmission over Internet for document delivery.

In the pilot for this project we used DOS machines at NAL to send documents over Internet through a VAX at North Carolina State University Computer Center and then on to Macintosh computers at the library over an AppleTalk local area network. Having shown that type of equipment was not a constraint, we accomplished the subsequent parts of the project on Macintosh II computers running the same set of software at each site. This project is scheduled for completion later this year. (Fig. 3)

OTHER PRESERVATION ACTIVITIES

In November, 1988, the National Agricultural Library organized and hosted the Conference on Application of Scanning Methodologies in Libraries which focused on current projects and techniques using scanning and optical character recognition technologies in the library and information community. Published proceedings are available from NAL.

NAL and the United States Agricultural Information Network (USAIN) jointly funded a two-day USAIN Preconference Program on developing a national preservation plan for agricultural sciences literature in October, 1991. This working meeting, which involved thirty librarians and archivists representing fifteen libraries nationwide, generated wide-ranging discussions on the need and potential for a nationally coordinated approach to preservation among agricultural libraries.

On August 17, 1992, NAL hosted a workshop on AgriLit: Electronic Access to Agricultural Literature attended by fifty representatives of the library community, agricultural researchers, and professional associations in agriculture. The purpose of the workshop was to educate professional societies and re-

searchers on the potential for making agricultural research available in electronic form. NAL collaborated with the American Society of Agronomy (ASA) in creating a CD-ROM containing the first sixteen volumes of the *Agronomy Journal*, and we have now begun work on the second disc in that series. Part of the agreement between NAL and ASA allows the Society to sell the resulting discs, while NAL is granted the right to freely use the page images to satisfy document delivery requests, etc. We are urging other agricultural associations to join with us in similar cooperative efforts to preserve their publications and provide electronic access to them.

NAL has recently agreed to archive the machine-readable data that was created to produce a seventeen-disc set of CD-ROMs containing publications from the Consultative Group on International Agricultural Research (CGIAR). We are now evaluating exactly what we should do. What medium do we use? What procedures must be established? Do we try to archive retrieval functionality or just the data? Many questions, few answers.

CONCERNS

In all our products, we have been careful to only include publications created by the federal government or with federal funds so we would not have to worry about copyright or intellectual property issues. One exception to this is the two-disc set on Acid Rain which contains Canadian federal publications. The University of Vermont produced these CD-ROMs as a spin-off of NATDP, and had to obtain copyright permission from the appropriate Canadian agency for each document. We feel that our current focus on putting association publications into electronic format in exchange for certain reproduction rights is a successful solution to a portion of the problem.

We are well aware that coping with hardware/software obsolescence will require an increasing amount of our resources in the future. What is somewhat unnerving, if it is a portent of things to come, is the large number of our system components that are already obsolete in such a relatively short period of time.

The National Agricultural Library has long been an advocate for standards adherence, and in our R & D projects we have incorporated as many technological standards as possible. Unfortunately, there don't seem to be too many standards on the "bleeding edge" and we have had to use proprietary hardware, software, and formats on a regular basis. Even some of the "standards" leave something to be desired: the Tagged Image File Format (TIFF) which is somewhat an industry standard apparently comes in at least seventeen different incompatible versions.

Almost all of our obsolete system components incorporated proprietary applications of technology which could not be transferred to offerings of other manufacturers. As standards become increasingly prevalent in optical technology our rate of obsolescence should decrease significantly.

BIBLIOGRAPHY

Andre, Pamela Q. J., "Evaluating Laser Videodisc Technology for Dissemination of Agricultural Information." *Information Technology and Libraries* 4:139-147 (June 1985).

Andre, Pamela Q. J., "Full Text Access and Laser Videodiscs: The National Agricultural Library System." *Library Hi Tech* 4:13-21 (Spring 1986)

Andre, Pamela Q, J., "In the Field of Agriculture, CD-ROM Delivers!" *CD-ROM EndUser* 2(3):26-27 (July 1990).

Andre, Pamela Q.J. and Nancy L. Eaton, "National Agricultural Text Digitizing Project." *Library Hi Tech* 23:61-66.

Andre, Pamela Q.J., "Optical Technology at the U.S. National Agricultural Library." *International Symposium on New Techniques and Applications in Libraries*, September 8-11, 1988 Xi'an, China. p. 125-134.

Andre, Pamela Q. J., Nancy L. Eaton and Judith A. Zidar, "Scanning and Digitizing Technology Employed in the National Agricultural Text Digitizing Project." *Proceedings of the Conference on Application of Scanning Methodologies in Libraries*, November 17-18, 1988: p. 61-73.

Andre, Pamela Q.J., "Towards the Electronic Library: The National Agricultural Library Experience with CD-ROM Technology." *CD-ROM for International Development*, proceedings of a workshop, Geneva, December 16-18, 1991. p. 1-8.

Blamberg, Donald L., Carol L. Dowling and Claudia V. Weston, *Proceedings of the Conference on Application of Scanning Methodologies in Libraries*,

November 17-18, 1988. Beltsville, MD, National Agricultural Library, 1989.

Bynum, Maria, "Preserving the Nation's Agricultural Literature." *Agriculture USA* #1833 (July 28, 1992). [Audio cassette (TIME: 13:30). Interviews with Pamela Andre, Alan Fusonie, and Ronald Young, NAL].

Demas, Samuel, "National Preservation Planning for Agriculture; Report on a Preconference Program of the 1991 USAIN National Conference." *Agricultural Libraries Information Notes* 17(11/12): 1-8 (November/December 1991).

Frierson, Eleanor G. and William Paisley, "From Paper to CD-ROM—Information Dissemination to Help Feed the World's Hungry." *CD-ROM EndUser* 2(3):34-37 (July 1990).

Fusonie, Alan E. and William G. Hauser, "Evaluating Optical Laser Disk Storage and Retrieval Systems for Non-Print Access at NAL." *Agricultural Libraries Information Notes* 14(11/12):1-9 (November/December 1988).

Fusonie, Alan E. and William G. Hauser, "The Forest Service Photograph Collection and Laser Disc Technology at NAL." *Agricultural Libraries Information Notes* 13(9):1-20 (September 1987).

Fusonie, Alan and Richard Myers, "Our Agricultural Landscape: Improving Image Preservation and End-User Access Through Laser Disk Technology." *The Journal of Imaging Science and Technology* 36(1):60-62 (January/February 1992).

Hanfman, Deborah T. "Laser Videodisc Technology for Storing and Disseminating Information." *Marine Science Information: an International Commodity*, edited by Grundy, Ford and Beardsley, IAMSLIC, 1986: p. 185-190.

Kelly, Sarah A., "Use of a Laser Videodisc System: Attitudes." *College & Research Libraries* (July 1988):357-362.

McCone, Gary K., "Digitized Image Transmission Using High Speed Telecommunications Networks." *New Horizons in Agricultural Information Management: Proceedings of a Symposium, Beijing, China, March 13-16, 1990*. Ottawa: IDRC, 1991. p. 92-97.

McCone, Gary K., "Image Transmission Over Internet: The NAL Experience." *Riding the Electronic Wave—Document Delivery*; Network Planning Paper, no. 20. Washington: Library of Congress, 1990. p. 69-76.

Miller, Mary and Jeanne Gleason, "Extension Reference Library—New Tool for USDA Professionals." *CD-ROM EndUser* 2(3):32-33 (July 1990).

Miller, Mary Guy, "The National CD-ROM Sampler Project." *Quarterly Bulletin of the International Association of Agricultural Information Specialists* 37(1/2):56-58 (1992).

Norris, Brian, "NAL is Fighting on the Front Lines in a Battle Against Time and Acidic Paper." *USDA News* 51(4):3,6 (May 1992).

O'Leary, Patrick, "The Electronic Library." [USDA TV News Feature. VHS Videotape; TIME: 2:40] (Interviews with Pamela Andre, Alan Fusonie, and Ronald Young, NAL).

Rivenbark, Leigh, "Agencies Stem Flood of Paper Through CD-ROM." [Interview with Gary McCone, NAL, and others.] *Federal Computer Week* (October 1, 1990):40-41,22.

Robb, David W., "Agricultural Library Plants Seeds of Data Storage." [Interview with Gary McCone, NAL.] *Government Computer News* (January 22, 1990).

Silver, Judith, "CD-ROM Technology's on a Roll in Federal Offices." [Interview with Gary McCone, NAL, and other.] *Government Computer News* (September 16, 1991):71,78-79.

Smith, James M., "Forest Service Photos Stored on Laser Disk." [Interview with Alan Fusonie and Ronald Young, NAL.] *Government Computer News* (February 4, 1991.)

Ulmschneider, John E., "Library Based Image Transmission Over Internet." *Quarterly Bulletin of the International Association of Agricultural Information Specialists* 37(1/2):77-83 (1992).

Zidar, Judith A., "Data Conversion: Moving from Paper to Plastic." *Proceedings of the National Conference and Educational Symposium on CD-ROM, SIGCAT '92*. Gaithersburg, April 27-29, 1992. [In Press].

Zidar, Judith A., "Optical Scanning and Text

Recognition: Technology Evaluation." *CD-ROM EndUser* 2(3):28-31 (July 1990).

Zidar, Judith A., "Retrieval Software Chosen for National Agricultural Text Digitizing Program." *Agricultural Libraries Information Notes* 18(3/4):14 (March/April 1992).

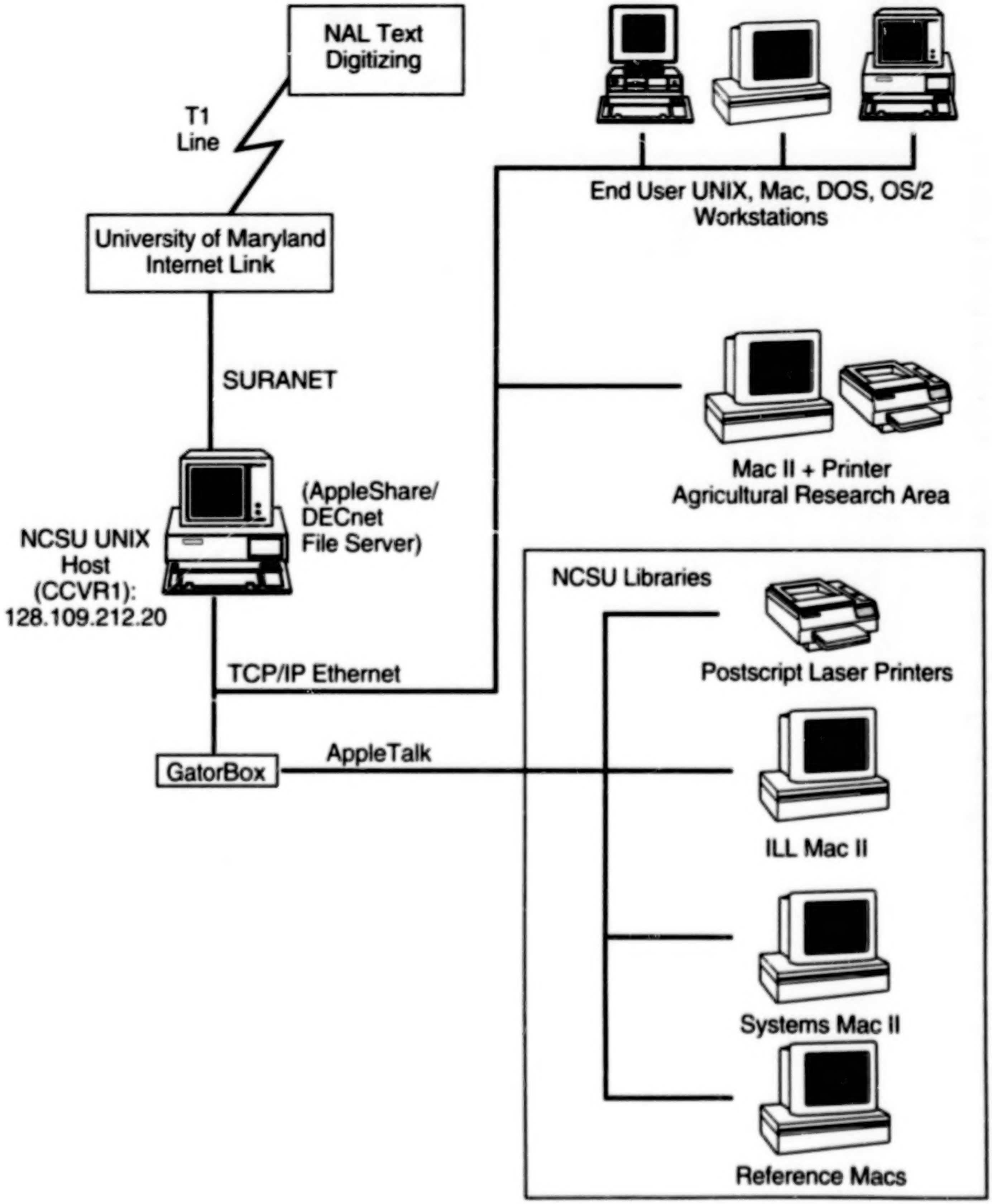
Zidar, Judith A., "Retrieval Software Evaluation Process." *Agricultural Libraries Information Notes* 17(1):10-11 (January 1991).

Zoellick, Pauline A., "The CGIAR CD-ROM Project." *Quarterly Bulletin of the International Association of Agricultural Information Specialists* 37(1/2):59-64 (1992)

Zoellick, Pauline A., "Issues Associated with Publication of CD-ROMs for International Markets." *CD-ROM for International Development*, proceedings of a workshop, Geneva, December 16-18, 1991. p. 61-77.

Gary McCone has over 15 years of professional experience at both the National Agricultural Library and the Library of Congress in library automation, bibliographic databases, and standards development. While at L.C. he was involved in the development of the MARC Holdings format, and now at the National Agricultural Library he is responsible for the online and CD-ROM versions of NAL's AGRICOLA database, as well as for the full-test and multi-media CD-ROMs NAL is producing, and NAL's research and development program.

Network Schematic



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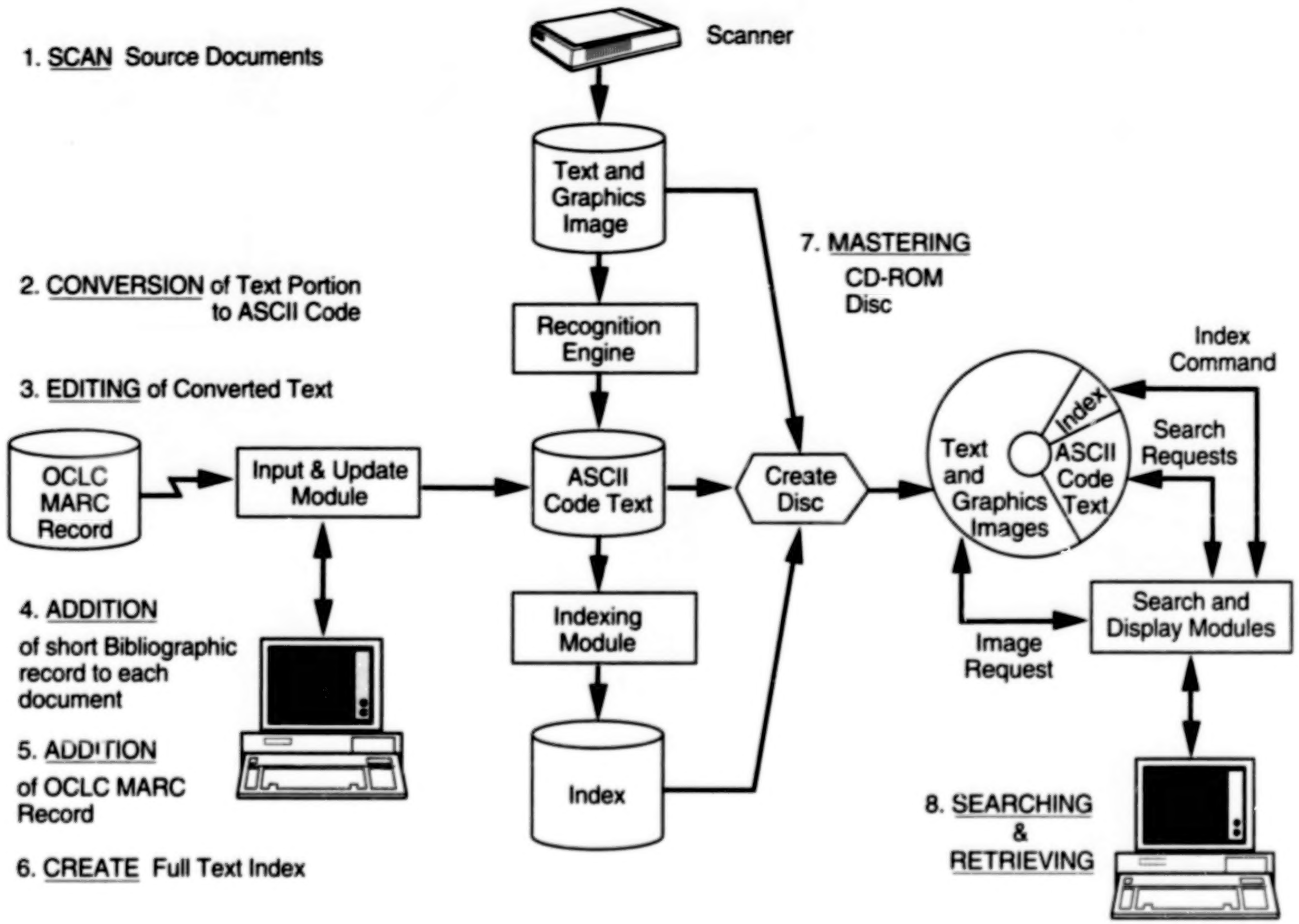
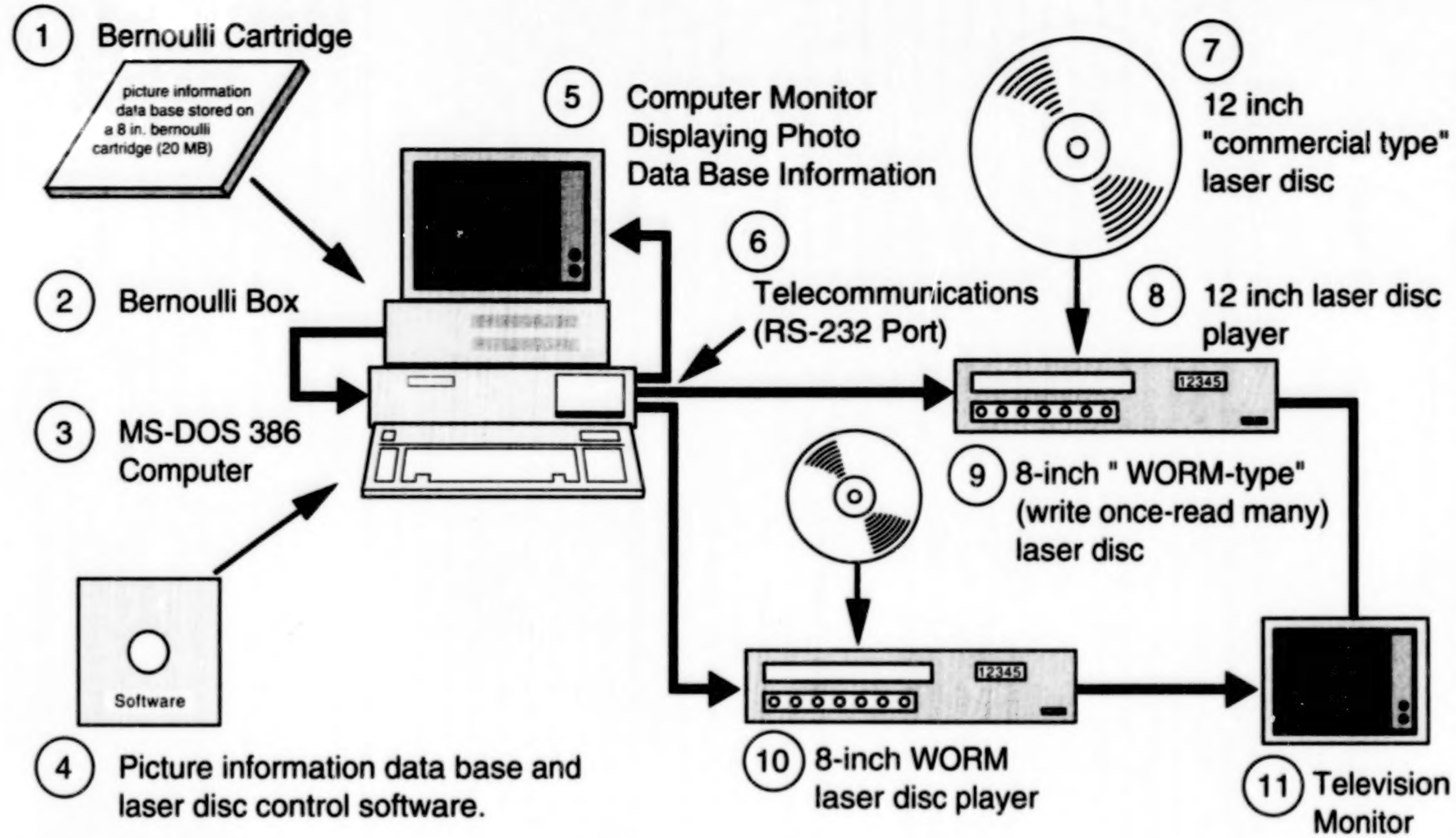
Text Digitizing at the National Agricultural Library



68

National Agricultural Library Laser Optical Picture Disc Display System



This system is used at NAL to display laser optical disc photo finding aids: 1) A 20-MB, 8-inch *Iomega* bernoulli cartridge containing the data base for the laser disc being viewed; 2) An *Iomega* bernoulli box data storage unit; 3) A Compaq Deskpro 386-130 Computer; 4) C-Quest™ Picture Data Base Software; 5) A computer Monitor to diplay information about the photo on the television monitor; 6) RS-232 Telecommunications Port; 7) The NAL-Forest Service Photo Collection Laser Disc; 8) A12-inch laser disc player; 9) An 8-inch, Panasonic WORM Laser Disc; 10) A Panasonic 8-inch WORM Laser Disc Player; and 11) A color television monitor to show the pictures.

53598A.1

DOCUMENT PRESERVATION BY ELECTRONIC IMAGING: STATUS AND DIRECTIONS

GEORGE R. THOMA, *NATIONAL LIBRARY OF MEDICINE*

There are many issues that need resolution before document preservation through electronic imaging becomes a reality. The advantages of electronic imaging (EI) are well known: easy access to document images through bibliographic databases, access from remote locations, ability to transmit the images over long distances over high speed networks such as the future NREN.

But clearly, there are barriers to doing this at present. The key concerns regarding cost and image quality remain high. These are largely technical barriers. But there are also institutional or administrative changes needed to make EI a reality in preservation.

To set the stage for discussion of these issues, I have listed some of the important ones comprising EI in the first column. In the second column, I have shown their current status ("where are we?"). In the third column I have listed some of the things that should be done. And in the fourth column, who can and should do them. I am lumping together disparate entities in this column; I am not differentiating between different types of industry, for example. "Industry" could stand for hardware, software manufacturers, system integrators, large companies and start-ups. "Research labs" could be industrial, or could be within the government or a national library. By research lab, I mean only a technical organization with the capacity to design and build prototype systems, and to use these prototypes as test beds to gather performance data that may be used to build performance and cost models, and to scale up from a small capacity system to something larger.

The functions of capture and QC have to do with image quality, which is determined by spatial resolution and the number of gray levels that can be detected. The scanning element is usually a linear CCD array. The scanning devices using the CCD array do about 200 to 600 dpi although there are labs that claim higher resolutions. Commonly the number of gray levels that can be detected is 8 bits (256 levels) though 12 bits (4096 levels) is not unusual. In one of our projects having to do with the archiving of digital x-rays, the capture is done at 12 bits.

To increase resolution, higher density linear CCD arrays are needed. In the last 10 years, CCD arrays have gone up from about 1024 elements to 4096 elements. Over an 8-1/2 inch dimension, this represents a scan density of 120 dpi to 480 dpi. There are some experimental ones that have a higher number of elements. For scanning, linear arrays have the disadvantage of having to move relative to the paper (either one may move). This is a disadvantage because of the time taken to mechanically sweep over a distance. Area arrays (two-dimensional) would solve the time problem by effectively grabbing the two-dimensional scene. The problem is that affordable area arrays are still capable of delivering very low resolution, about the resolution sufficient for ordinary television, about 400 x 400. The minimum size required to deliver a 200 dpi image for a standard page would be 2K x 2K, but these are very expensive and commercially not feasible for everyday scanners.

It is not clear that unlimited spatial resolution or gray scale is the answer to high image quality. Some years ago Bell Labs did work in trading off spatial resolution vs. gray. There is some evidence that subjective image quality improves when multiple gray levels are included: so, rather than having 400 dpi spatial resolution at 1 bit per pixel, it might in fact improve the image by doing 200 dpi at 2 bits per pixel (4 levels of gray), without increasing the image file size. I am not aware of recent work in this area, but this might be something to be tackled by a research lab.

Image enhancement includes any process that improves the captured image: contrast modification, so that the poor contrast in the original is corrected to give black text to white background; variable contrast correction to remove stains or bleed-through; algorithms to remove page edge effects, such as unsightly borders. Algorithms exist for all of these, but more work is needed to automatically, reliably and quickly correct these deficiencies, especially variable contrast and borders.

QC is related to ensuring good image quality, but it may be at a later stage. Some of the problems corrected at this stage are: skew, where the image orientation is not quite the same as the page orientation (this might result in some loss of material from the

70

page and also prevents accurate OCR if at some point it is desirable to convert the bitmapped image to ASCII code, for machine searching or compression); page shuffling, which is a problem when loose sheets are being fed in, but not if a bound volume is being scanned; missing or added pages, which is a problem if the operator is not alert while scanning. These problems are manually handled currently, but work is proceeding in automating page number detection, skew detection and correction.

Tagging and indexing are steps to identify the document to the machine, either as a whole entity (a book or a journal issued) or as portions: chapters, articles, tables of contents, etc. The point of this identification is to enable access and retrieval. At present tagging and indexing are done manually. Automated page detection and perhaps the OCR of certain printed information on the cover page, title page, or the first pages of chapters or articles should partially automate this process.

The current density on optical disks seem to be in the 6 GB range for a 12" diameter disk. The claims to media longevity seem to have peaked at 100 years.

Standards organizations with the participation of industry have managed to standardize compression techniques, with some salubrious effects. For instance, the well-known CCITT G3 standard has greatly contributed to the widespread use of fax, so that anyone with as little as $500 can buy a fax machine and be assured that he can send or receive a page in about 1 - 1-1/2 minutes. Most importantly, he can rest assured that he can communicate with fax machines anywhere in the world. For image storage, the CCITT G4 standard does allow better compression than the G3 standard and is in fact currently the best way to store two tone printed material. Other standards, JBIG, for instance, are on the drawing boards. Whether or not they offer substantial improvements in compression ratio remains to be seen.

Now we come to an item where technology per se is not the issue, organizational attitudes are. If preservation is to be done by electronic imaging, we need to live with the fact that the only constant feature of technology is that it will never remain the same. Media density will go up; workstations that scan documents, access the images, retrieve, display and transmit the images, will all change, either in operating systems, file formats, or application level software. That is all to the good, for in our everyday work, we know we periodically upgrade our personal technologies for the advantages the new upgrades bring us. Even at the simplest, word processing level, who still uses WordPerfect version 1? I do not know anyone not using WordPerfect version 5 or 5.1.

But coming back to preservation by electronic imaging, this presents a problem. An institution now has to do more than provide a climate controlled or air conditioned room for the preserved material. It has to make arrangements for data on this year's disks to be transferred to new media as the years roll by, and long before the 30 years or 100 years the disks are supposed to last. Here perhaps the national libraries can take a lead. They can design the organizational structure needed to implement this periodic refreshing, so that access to the information on the media is always assured.

George R. Thoma received the B.S. from Swarthmore College and the M.S. and Ph.D. from the University of Pennsylvania, all in electrical engineering. He is the Chief of the Communications Engineering Branch of the Lister Hill National Center for Biomedical Communications, the research and development arm of the National Library of Medicine. He has developed and evaluated systems involving image processing, document image storage on digital optical disks, high-speed image transmission, analog videodiscs and satellite communications. Dr. Thoma's previous experience at the General Electric Company, AII Systems and the University of Pennsylvania had been in the application of satellites in voice and data communications, video distribution, navigation and surveillance.

Document Preservation by Electronic Imaging

Function/Activity	Status	Directions	Organization
Capture	Spatial Resolution (200-600dpi) Gray Resolution (8-12bits) Enhancement	Tradeoff Spatial and Gray Resolutions for High Image Quality, CCD Development	Industry, Research Labs
Quality Control	Manual (Operator)	Automatic Skew Detection, Page Orientation, Page Number Detection, Bordering	Industry, Research Labs
Tagging, Indexing	Manual (Operator)	Automate Page Number Detection	Industry, Research Labs
Optical Media Density	6 GB (12")	Materials Science	Industry
Optical Media Longevity	100 Years	Material Science	Industry
Compression	CCITT G4, JBIG	Higher Compression Ratio	Industry, Research Labs, Standards Organizations
Periodic Data Transfer	None for EI Preservation	Institutional Arrangements	National Libraries, Major Libraries
Standards Development	Compression	File Format	Standards Organizations

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STANDARDS IN THE CD-ROM COMMUNITY

MIKE RUBINFELD, *NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY*

As Basil stated, my name is Mike Rubinfeld, but it's a misnomer to call me Michael, since my real name is Myron. Most people do make that mistake, however, because I am commonly referred to as Mike.

I'm currently associated with the National Institute of Standards and Technology, formerly known as the National Bureau of Standards. My esteemed fellow colleague, Tom Bagg, is also with NIST. We're involved in numerous activities and I'm proud to be a part of this conference. We're currently involved in a wide variety of research, including all the physical sciences. We have a national computer systems laboratory, where we do formulate standards for the federal government. We also provide research and development into new techniques involving computer technology and the use of data.

We are in the digital age, for better or for worse. It's not going to go away, ladies and gentlemen. It's just going to grow in acceptance as time goes on. Right now, there are economic factors that prohibit the general population from fully using this technology. The day of the library without walls will soon be upon us. We will have a fully digital form of a library where you'll have storage mechanisms that have massive amounts of data in them and are able to transmit data across networks to various points. But as Tom Bagg pointed out, and I have to agree with him, today, at this point in time, there are no real standards in place that will enable this type of technology to be used by us in rapid succession. There are just too many roads that the industry is following, and one of our major obligations as part of the National Institute of Standards and Technology is to try to get this industry, in total, to follow at least a uniform path. So that we are all talking from the same prayer book, so to speak.

I think the majority of the problem is one of semantics. If you look at all the research that's going on, people don't understand what one another is talking about, because they use the terminology in so many different ways. Tom was explaining his idea of graphics as something else other than what the digital community thinks of graphics. The term I come across time and time again is client-server architecture. Well, who are the clients and who are the servers? It depends, if you're a lawyer, you know that you're the server and your client is the poor fellow coming in to obtain your services.

In the digital community, it's commonly referred to as a client application, one which performs a certain set of functions for the end user. The server is the platform and the underlying computer services that translate the client application into a number of services, such as communications, or printing.

What I intend to do is give you a survey of what we are doing in one area that I'm heavily involved with, and that's optical storage technology. You're all here because you're preservationists and you're interested in new and different ways to preserve information. I'm coming from the aspect of accessibility because that's what we're in the business for; to promote the most standardized form of this accessibility throughout the industry and throughout the world.

I'm going to concentrate on one aspect of storage technology, optical storage technology, and a device called CD-ROM. I'm sure everybody in this audience is well aware that a CD-ROM is commonly referred to as compact disk read-only memory. That's what the acronym stands for, and I don't think it's changed in its use. It's based on an invention from the Phillips-Sony folks that provides a certain diameter disk of polycarbonate structure that enables digital recording of information being burnt in by a laser mechanism that causes actual bits and troughs in a spiral shaped track that extends about 2.3 miles if you extend it from end to end. But it's about 1.5 microns that differentiate the next track from the other track.

This digital form of optical storage technology is a transient mechanism. Yes, probably maybe two or 300 years from now, you'll be hard pressed to find a reader for this particular mechanism. But in the interim, for at least the next 25 or 50 years, I think there will be readers around that will be sufficient in number to enable the use of the data on this mechanism to proliferate throughout the country in a cost effective manner.

Just look at magnetic tape. I mean the magnetic tape drive right now is coming up on its 50th year anniversary soon, and there are still tape drives in existence out there. They're higher density drives, but they still read seven track tapes. There are also 9260 bpi tapes and even higher densities.

Let's talk a little bit about CD-ROM standards history, just to familiarize yourselves again with it. I'd like to spend some time on an architectural model for this digital storage technology mechanism and the reason for this architectural model. After that, I will talk about related standards initiatives.

It all started out, with the compact disk that was really an audio mechanism that enabled music to be translated into digital form using a laser burning mechanism, creating a constant linear velocity read-only device. And this standard was put forth by an industry consortium, namely the Phillips and Sony people, and it's commonly referred to as the Red Book. This Red Book design for the 120 millimeter disk and all the physical attributes of that disk, including the center hole, resulted in an international standard called ISO 10149. So any of you who are interested in the physical attributes of a CD-ROM, I refer you to that particular standard.

The next thing that happened that made a CD-ROM a CD-ROM was the ability to put not only audio data on this mechanism, but digital data of other sources, such as images, text and so forth.

This standard came about through a group called the High Sierra Group, and they came up with what they call a volume file formatting standard. This volume file formatting standard resulted in another ISO standard called ISO 9660, and that is the one standard that differentiates CD-ROM from any other optical storage mechanism, because this particular standard is more pervasive in its use throughout both industry and government than any other optical form known.

I may have an argument about that from my fellow colleagues, but I'm told that right now, this particular media does not necessarily represent the best type of media, but at least it's the most pervasive and it's very inexpensive to manufacture. Right now, you can stamp out these CD-ROMs and they are used for dissemination purposes and promoted by the publication industry. They can stamp these out at roughly $1.50 a copy at their own cost and I think that cost is even going down somewhat. I think it's, right now, around the 80 cent mark.

So when you go and buy a digital audio disk from your favorite outlet and you're paying $18.00, well, you know the markup you're paying now because it's costing them 80 cents to produce that piece of polycarbon.

Then after the 9660 was established, people in the industry felt that there was something lacking. They didn't know how to combine the digital data quite with the audio data and they came out with an interim standard called the XA standard. This is called the interleaved audio, where audio data is interspersed with the digital data or image data.

One of the biggest problems, however, in the CD-ROM industry at the present is that the search and retrieval aspects of the data are inextricably combined with these CD-ROMs, in that you could not separate the retrieval mechanism from the data itself and people are having to pay an exorbitant price for software that they would have to purchase that would be on the CD-ROM in order to access that CD-ROM. This is one of the areas that we are trying to conquer because we feel that you should be able to purchase your own search and retrieval software, if you wish, and then access any CD-ROM based data off of any CD-ROM. This is utopia. It doesn't exist today. But these are the areas that we are pointing towards right now.

And in order to accomplish that, what we have to visualize is that all these vendors must talk a similar language in order to make this happen. In order for them to talk a similar language, they must have an architectural viewpoint in which to view their software in context with the data on a CD-ROM. So there's a need for common understanding, and that's what the architectural model is supposed to represent. It's a hierarchical view that we map into ISO standards that exist already.

We, at NIST, have formulated from the ISO standard a new standard called Open Systems Environments, which is based on the OSI standard, and that is also using layered representations.

From that perspective, we've developed an Application Portability Profile. This profile is for computer systems in general. I'm laying this groundwork because all information that's transmitted across networks and stored on optical media will have to follow certain concepts that we are trying to establish throughout the entire computer industry. We have a network management framework combining systems management, network management, and applications management.

Just to give you an idea of what we consider to be an image management architectural profile — and this doesn't represent optical storage technology per se, but it represents storage management of digital

74

data in general — we look at a physical format which is at the bottom layer that is represented in CD-ROM by that ISO 10149. Now that can be replaced. And these architectures enable innovation to take place, that you can transpose new and better mechanisms as time goes on.

For instance, in say 25 to 30 years from now, you're going to start to hear the word holographic memory, and this is right now in the laboratories, where they can store terabytes of information on about a one-inch cube. This is where the technology is going eventually and there's no mechanical devices involved in it. It's strictly a laser beam accessing a molecular lattice within this holographic cube and the data can be retrieved. But right now, today, we're talking about CD-ROM being in this physical formatting layer.

The logical format likewise will have structures that we can establish today that could be applicable for years and years to come. These are more or less semantic structures than anything else and have little to do with the innovative technology.

Encoding is another area that's undergoing great and dramatic change There are numerous standards involved in encoding. Let's start with the basics. You have ASCII encoding for text, that's an international standard. Now there are image standards that are being promoted, such as the JPEG, which is the Joint Photographic Experts Group. They just came out with a lossy compression technique that allows a very good representation of digital imagery up to a point. There's argument about what kind of magnification can you get to where you start to get very lossy imagery.

Then there's the MPEG compression, which is what the motion pictures expert people are coming up with. It deals with algorithms for moving images, such as motion pictures, which is a series of frames, and it's based on frame technology.

Further, you have encodification based on a new technology that I've seen recently introduced where they are developing fractal image compression technology.

Now this is a different way of representing imagery, as opposed to the optical or the standard way where you take a picture of something and you use optical means to represent that digital image. They represent the digital image through mathematical representations or equations. So you can see right away that if you can represent the image in good form through a mathematical equation, it could save millions of bytes of storage. And they're talking about 800 to one, 900 to one, 1200 to one compression ratios using fractal image technology.

The question there is this reality or is this a version of one's figment of reality. Again, we're getting into a social and philosophical issue where one can argue that even an optical image is not quite reality, but it's a perception of reality based upon the light waves that come from that object that reach our receptors in our eye and that is strictly perception. It may not have anything to do with reality, but that's an argument beyond this talk here.

Encoding structures also involve such things as encryption. We were talking about the rights of intellectual property and also the protection of privacy. Encryption is a very powerful mechanism to enable the safe keeping of information from unauthorized use or unauthorized eyes and this digital technology enables that to happen.

There may be other areas, such as data interchange, that we're interested in, interchanging the data so that it's most useful in a retrieval format. Tagging strategies were developed for this purpose as an international standard that has been promulgated through ISO and it is widely used throughout the federal government.

Standardized generalized markup language — structured generalized markup language. There is also a competing standard that has also been developed under ISO and that's called Office Document Architecture. This is an architectural language that allows one to view a compound document and tag that document so that you can separate the text from the images and have all the various meanings go along with that.

Just to put it in the CD-ROM perspective again, and I'm just showing you what the CD-ROM looks like on each of those levels. Moving up the strata, we have the indexing layer. This layer is probably the least understood insofar as standards are concerned. There are a lot of proprietary standards out there, and this is the one area that we are arguing constantly with private industry about because they feel that it's their proprietary edge to sell their software based on their own indexing strategy, and to open up the index would give their profitability away. We don't feel that way. I think that there can be such a thing as a common indexing strategy that's used and it could be based on numerous techniques such as V-Tree, binary searching, and so forth.

A strategy has been proposed at Carnegie Mellon Institute under the auspices of an Air Force contract. They developed a complex indexing architecture standard, and this standard has not been put through the standards community yet, but it is a proposal I think for future reconsideration.

Now we're moving up into the area that's probably least understood, but is probably of most importance to the standardization of this information interchange, if you will, from the optical storage platters to and across networks to the individual terminal.

This area called the CD-ROM application programming interface, is an area that ties the client application, which is your search and retrieval application, to the server, which is your search retrieval engine. There are a few strategies that have been proposed, one by the intelligence community called the CD-RDX which is one type of application programming interface. It's a set of protocols that allows the client application to talk to the server through this uniform set of protocols. By using this, you can have a client application on one platform and a server on another platform, say across a network, for example.

There's another proposal that's been proposed by the Air Transport Association and the Airline Manufacturers Association, called the Structured Full Text Query Language. This also is a programming interface and it is also used to communicate between the client applications and the server. And, of course, there's the client application at the top which, above that, you have a user interface.

There are standards out there now that describe various user interfaces, such as your graphical user interface such as Windows. You've heard of Windows 3, which is really not an international standard, but it's a de facto standard. There is also X-Windows in the UNIX community and there are just a number of different standard interfaces out there.

Yes, there are standards that do change out there, just as there are hardware and software services that change. But I think if the standard is a good standard, if it takes into consideration innovation of technology, it can be used for some time to come.

I'm going to end up by giving you a little overview of where we are today with respect to these standards initiatives. Right now, as I just showed you, this architectural model is now under development in a committee of the IEEE computer society called the Committee for Optical Storage Technology in Multimedia Platforms. We have three working groups established under this committee. The first working group was charged to write a CD-ROM architectural model, and I am chair of this particular working group.

There are two other working groups in this IEEE Committee. The other working group is called the Rock Ridge Extensions Working Group. Primarily, this working group has taken the work of an industry consortium called Rock Ridge. It was a consortium made up of Sun Microsystems, Hewlitt Packard, Apple Computer, Microsoft. There's about 21 companies in all. I participated in that particular initiative and they've gone as far as they could go with that particular project.

The Rock Ridge work is simply an extension to the ISO 9660 volume file structure. For those of you who are interested, I'll just go into it briefly. The volume file structure right now has been designed primarily for the DOS user, since you have only eight characters and a three-character extension that you can use for a name, and that's the naming convention that's used for this particular standard. They also have another limitation in the number of subdirectories that you can have under the ISO 9660, and that is eight subdirectory levels.

There are folks, who are promoting UNIX environments and open systems environments, that want to be able to use more extensive naming conventions, i.e., 32 characters, up to 250 characters if you wish for a name. And, also, they would like to have as many subdirectory levels as they wish to have, and they proposed and extension to 9660 that is 100 percent backward compatible, with the ISO standard. If you use the Rock Ridge extensions, an ISO 9660 user, other than Rock Ridge, will be able to access the information also. Hopefully, these extensions will end up as an addendum to 9660 in the ISO community.

There is a competing strategy that has evolved simultaneously from a group called the Frankfurt Group. This group is looking at a different segment of the industry and that is "write once" optical technology. Those folks have the problem whereby when you're writing information to an optical storage mechanism, i.e., the WO technology, which is your 120-millimeter technology that corresponds with the CD-ROM, but it's a write-once mechanism — I think there are a few drives out there now. Phillips makes one, Sony makes one, JVC. There's probably a couple more, but that's all I can recall for now. These mechanisms must have the ability to intermittently write and be able to support the ISO 9660 structure.

The Frankfurt Group developed another set of extensions that allows intermittent writing and that is in a committee called the EMCA/TC15 Committee, which is the European community, and they are going to fast track that into ISO.

We also have an AIIM Committee that's been established for raster image tagging structures, and this is committee 15.6., and we're in the first draft of that document. We will be able to universally tag raster image documents as opposed to vector images. Our next meeting is scheduled within the month and we should be meeting to vote on that draft.

Finally there are some API proposals that are out there. We have an ISO Committee that's formed that I'm part of, called Committee AD that's looking into these APIs that I talked about, called SFQL and CD-RDX and there's one other submitted by Silver Platter which is a software/hardware vendor in the CD-ROM community.

I believe that all the standard initiatives that I have mentioned here today represents the current on-going efforts within the CD-ROM community. Thank you for your attention.

Mike Rubinfeld has worked in the field of Computer Sciences for over 30 years. Presently, he is a Computer Scientist at the National Institute of Standards and Technology (NIST) where he is currently tasked with developing a CD-ROM architecture. He is chair of SIGCAT's SIGSTAND comittee and chair of its First Annual National CD-ROM Conference. He is a member of NISO Committee AD, a member of IEEE/CS Optical Storage and Multimedia Committee, the AIIM Committee on Raster Image Tagging Structures, the Department of Commerce Data Management Committee, and the Department of Commerce Sub-Committee on CD-ROM.

Overview

- CD-ROM Standards History
- CD-ROM Architecture Model
- Related Standards Initiatives
- Summary & Questions

53598E-1

CD-ROM History

- Red, Yellow, Green and Orange Books
- ISO 10149 Standard
- ISO 9660 Standard
- XA – Interleaved Audio

53598E-2

CD-ROM Architecture Model

- Need for Common Understanding
- Based On Data Storage Model
- Hierarchical View
- Relationship to the OSE Model
- Layer Representations

53598E-3

What is the APP?

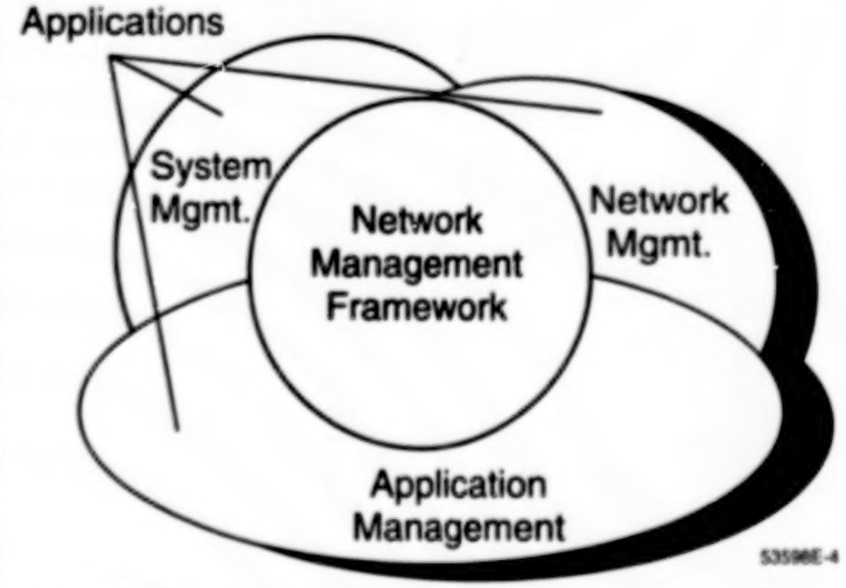

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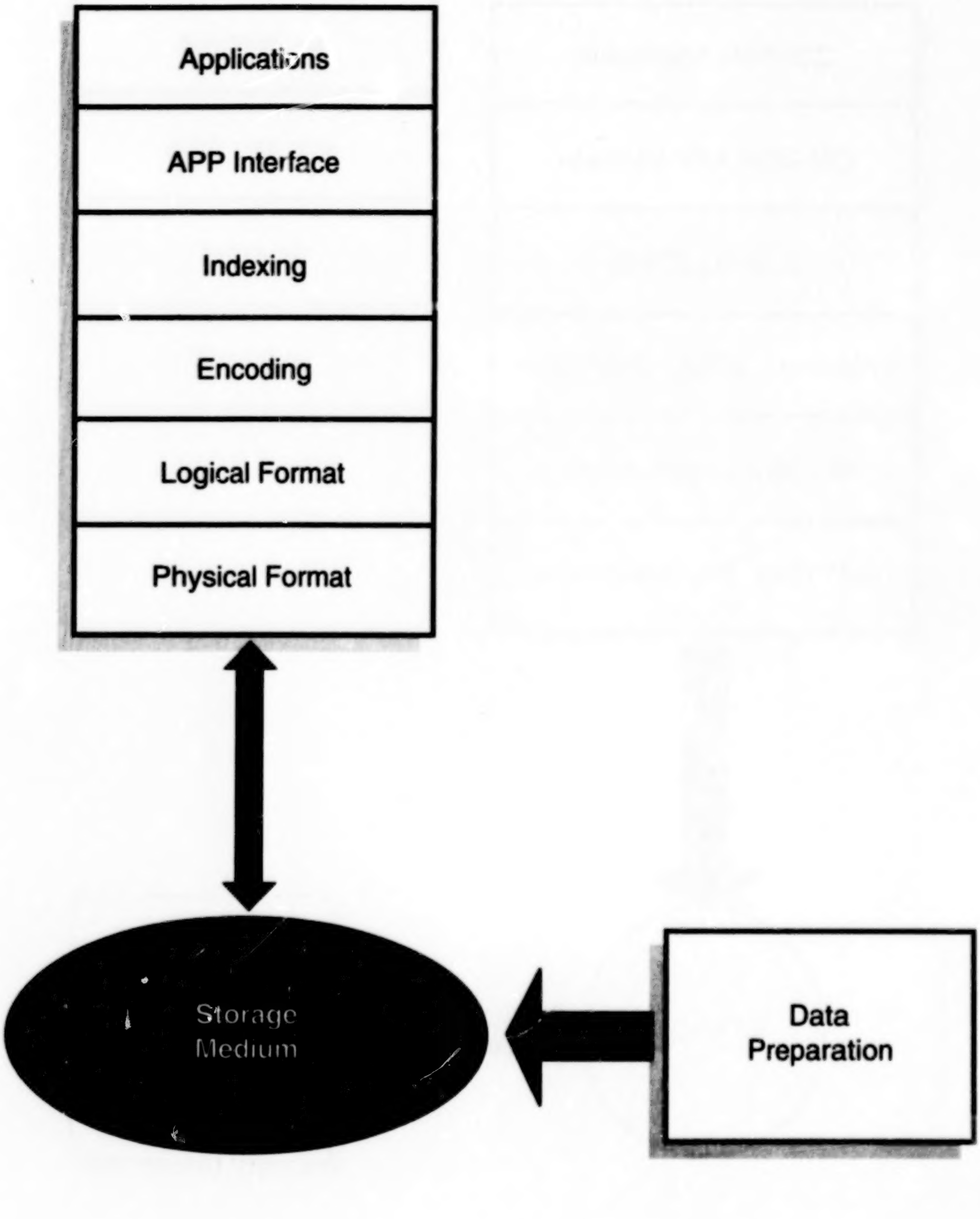
Image Management Architectural Profile



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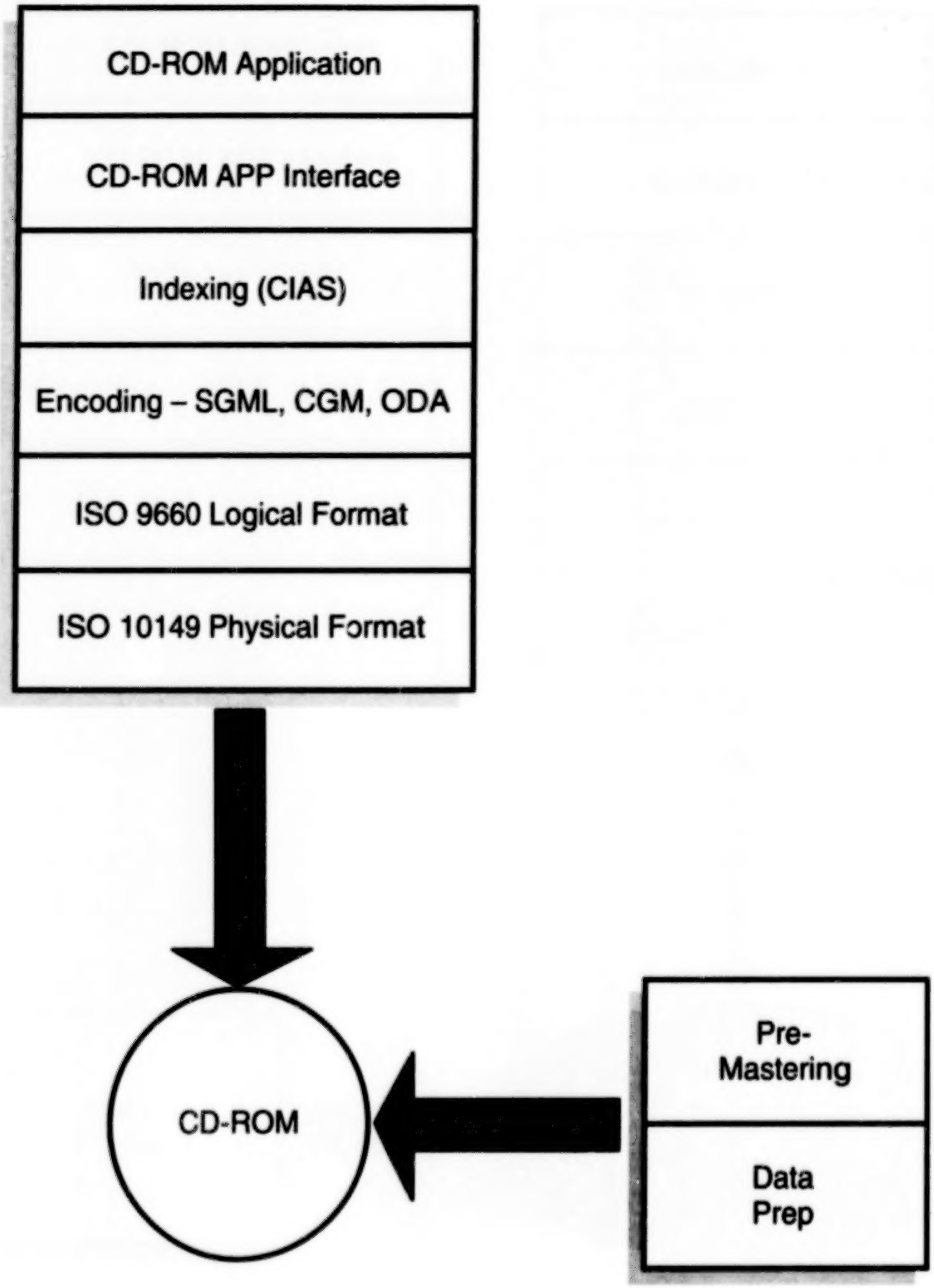
CD-ROM Management Architectural Profile



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Physical Formatting Examples

- ISO 10149 Format
- XA - Interleaved Audio
- CDI
- Sony Discman
- WORM Drives
- Video Disk (12 inch media)

53598E.8

Logical Volume-File Structure Examples

- ISO 9660 Volume-File Structure
- Rock Ridge 9660 Extensions
- Frankfurt Write-once Extensions
- Future Proposals

53598E.9

Encoding and Data Interchange Examples

Encoding: ASCII, TIFF, Group 4 FAX Compression, Encryption, etc.

Data Interchange: SGML, ODA, Hytime, Raster Image Tagging, etc.

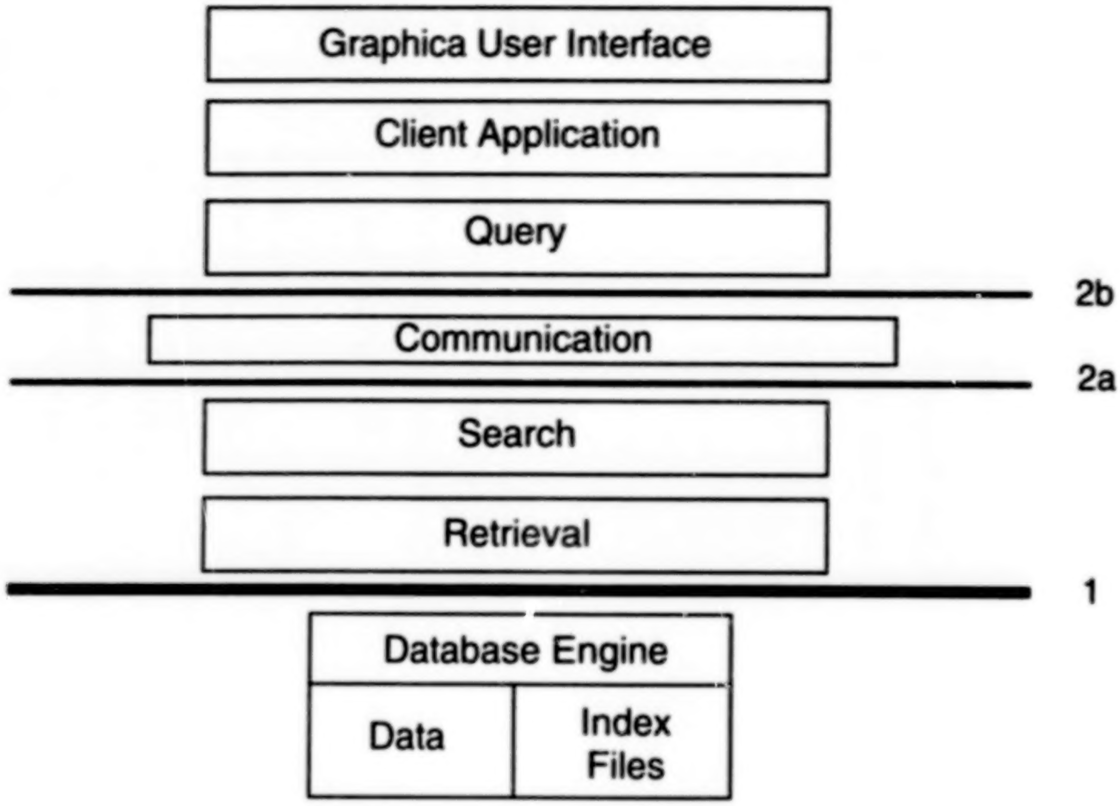
53598E.10

Status of Standards Initiatives

- CD-ROM Architectural Model
  - IEEE/CS Committee
- Rock Ridge Extensions
  - IEEE/CS Committee
- Frankfurt Proposal
  - ECMA/TC15 & X3B11.1
- Raster Image Tagging Structure
  - AIIM Committee
- API Proposals
  - NISO, X3H2, IEEE/CS

53598E.11

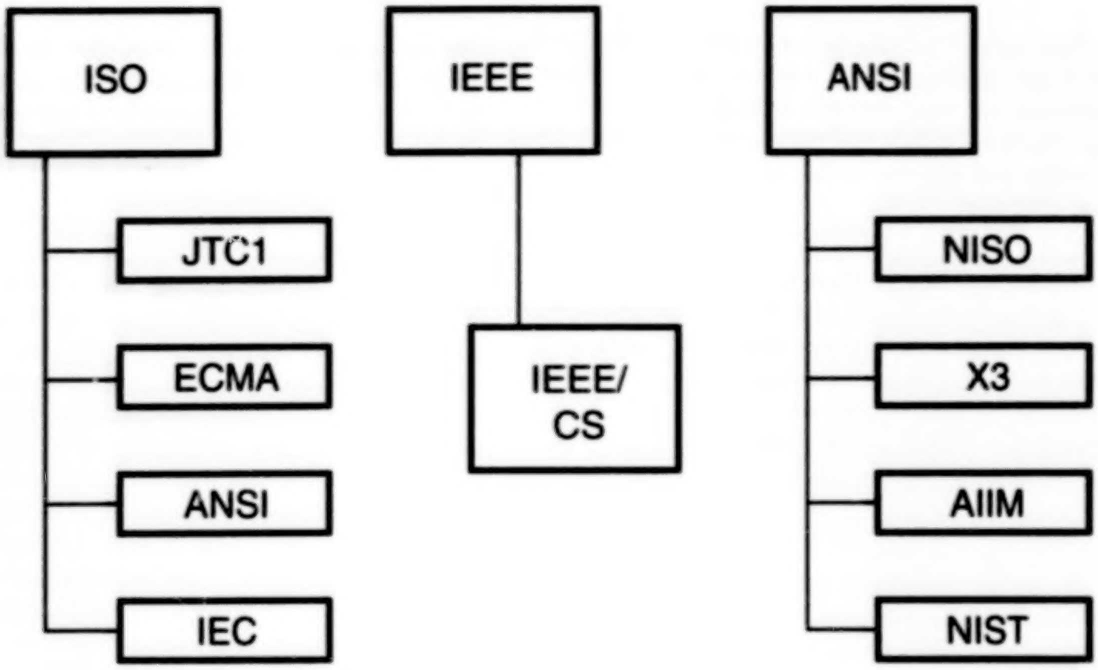
CD-ROM Mixed Mode Reference Model



53598E-7

82

Accredited Standards Organizations



53598E.12

DOCUMENT IMAGE MANAGEMENT

JUDITH C. RUSSELL, *GOVERNMENT PRINTING OFFICE*

I am very pleased to be here with you today and to have the opportunity to talk to you about some document image management activities that are currently employed at the Government Printing Office for production and dissemination of government information products.

When Basil Manns first called, my reaction was, well, it seems funny to ask for GPO to be at a meeting on preservation because people think of us more as a generator of information than as a preserver of information. But I believe that the changes in the way government information is produced and disseminated do provide significant potential for preservation.

I'm going to take a minute because, looking around the group, I see some people here that may not be familiar with GPO. I want to give you an idea of who and what we are because I think it will give a context to my remarks. We are a Legislative Branch agency, but we were set up as a service bureau to the entire federal government for printing services. We have over 5,000 employees. We are the largest industrial employer in the District of Columbia. That's sort of an interesting way of looking at us because we really are a manufacturing facility and that's unusual in the context of a government agency.

GPO has three major functions, printing, (and we do have a lot of printing presses in that building), printing procurement, and the dissemination of government publications. We are a billion dollar agency, of which about 700 million dollars is spent on procured printing, primarily for the Executive Branch of government. As a result, we're a very large procurer of services from the private sector.

About 200 million dollars is spent on in-house printing, primarily for the Congress. We are a Legislative Branch agency. We print the Congressional Record, bills, reports of hearings, but we also print passports, postal cards, slip opinions from the Supreme Court, the Code of Federal Regulations, the Federal Register, the budget, Statistical Abstracts, the Government Manual, just to name a few.

We spend about a hundred million dollars in dissemination activities under the direction of the Superintendent of Documents, who is my boss. So that's where my own particular responsibilities lie: Disseminating the information once it is created.

What I want to talk to you about today, though, is the way that we're changing our production techniques and how those changes may affect the way each of you can look at information and work on preserving information in the future. We have been working for more than 15 years now on Atex photocomposition equipment which generates text, but which must have graphics and a lot of more complex tables and things stripped in at the time that you're ready to go to press with it. We are now going to use a system to typeset Congressional bills, which is an example of a new production technique that's beginning to be expanded into other parts of the agency. And I think when you look at us in a year or two, you will see this as the dominant way of producing text. Additionally, it has some significant implications for having digital information available for your use.

Right now, when we key in Congressional bills, we use a new PC based system incorporating GPO-developed software. It's software that's in the public domain, called MicroComp, for microcomputer photocomposition. This creates an ASCII text file with imbedded GPO locator, or typesetting, codes. (We are, as an agency, moving to SGML is the most common international standard now for markup language. But the GPO locator codes were developed before SGML and are very comparable in terms of their functionality).

The file that's created by MicroComp can then run through a program that, in effect, typesets the document and outputs camera-ready copy from a personal computer to a high resolution Postscript-compatible laser printer. The output from the laser printer (at the moment, we're doing it at a thousand dots per inch) is used to create plates that go directly on the press. This production method has a number of benefits. Under the old system, strip changes were frequently made because it was both costly and time consuming to correct the data file and rephotocompose a document. After production, the data file then had to be edited to conform to the printed document, and

84

many times it wasn't because the printed document was what was desired and there was no incentive to go back and edit the print file.

The editing also tended to get a second priority, even when it was going to be done for archival or other reasons. Rather than going back and cleaning up a data file from a job that had already been completed, the next job coming through tended to get priority,

Now, it's both cheaper and faster to correct the data and run new camera-ready copy, and as a result, we have a clean data file when taking the document to press. These data files are now stored at GPO in two formats. One is an ASCII text file with those locator codes in it and the other is a Postscript file that effectively creates an image of that typeset document.

We've acquired a juke box for storing these images and the ASCII text files on write once (WORM) discs. We're experimenting with a number of different types of Postscript printers. The one we seem to be focusing on right now is one that can do 17 pages per minute and produces a 600 dots per inch output, but seems to be good enough for creating high quality copy for taking to press. Eventually, we expect that technology will let us go directly to a plate, without that intermediate step of putting it on paper and then shooting a plate.

What this is allowing us to do, then is to create a complete document. The text file in ASCII effectively gives us access back to permit search and retrieval, but at the same time, the Postscript file allows us to reproduce the actual image of the document exactly as it appeared when it went to press.

We can incorporate graphics, formulas, and other kinds of camera ready material by scanning and storing those images as encapsulated Postscript and actually imbedding them in the document. So now it isn't just text, and somewhere separate, those various images that had to be stripped in; it really is a total document.

The bills are particularly interesting, and I think representative of where we may go with this because we don't print a large quantity of most bills. Those of you who follow Washington know that lots and lots of bills get introduced, go to committee and die there. So when we produce a bill, we print a fairly limited number of copies, not knowing whether it's going to be in wide demand or not. This new use of technology now gives us an opportunity to really look at this as a print-on-demand capability, at GPO, on the Hill in the document rooms, in the GPO bookstores around the country, or at other sites that might have access either to our own system or to any kind of remote storage of those Postscript files.

We're in a transition period now, but this same technique is already being employed for parts of the Federal Register, the Code of Federal Regulations, and the Congressional Record, which are three of the most important publications that we print. As it spreads, it will be used for other documents as well. I expect that by this time next year, you'll find that almost all of the Federal Register, CFR and the Record are being done in this manner.

Think about what that means. If a critical Federal Register document is issued this morning, here in Washington, we could actually transmit it to the West Coast as a Postscript File. Somebody could print it out there and have an exact image of the document, not waiting for somebody to fax it; not dealing with waiting for the Pony Express to take it cross country at second class postage rates; but a real time exchange of the true image. I think, this really will make a very big difference in the way that we do business, and also in the way that the agencies will do business when they come to use GPO.

I'll tell you briefly about our new bulletin board service because I think it is also a part of this whole issue of how we're disseminating these images, once they're created.

We started it on September 1st, 1992 as a general bulletin board which many agencies are going to use to distribute a variety of data files. But the application that's relevant today is an application from the Environmental Protection Agency. They now prepare at EPA their own Federal Register submissions with all of the locator codes in them. EPA is submitting, in effect, to the Office of the Federal Register and through OFR to GPO all of the typesetting for that document. So now, simultaneously with publication in the Federal Register, EPA is putting up on our bulletin board a Postscript compatible file, a WordPerfect version which can include the WordPerfect compatible graphics, and an ASCII format. EPA is going live the same day in those three electronic formats and people can download them and print them locally.

At this point, EPA is not actually generating a Federal Register file complete with page numbers and things, but using the EPA file, we are generating an image that looks very much like the front page of the

Federal Register. The sample I've given you has some tables in it. It's using three-column, full typesetting. There's even, in the first one they did, a full-page graphic which is there, incorporated in the document. So we're now looking not at something just like an online text retrieval system. When you look at the LEXIS service on Mead Data or at WESTLAW or some of the other services, they're delivering text, but they don't yet have the capability of delivering those graphics, and you're not seeing that typeset document. So this is an alternative way of delivering that information and you've already created your digitized form which you could store and use for your preservation and subsequent retrieval.

I've also included in the sample about the bulletin board this little handout. What this does is show the first screen on the bulletin board and also the screen for going into the area of the bulletin board where the EPA files are stored, and then a list of the files. You can get a sense of the size of the files and the price that we're charging, because we are a cost recovery agency. I think it was Gary McCrone who was talking earlier about needing a megabyte for a page of data. The Postscript file for this Federal Register document, which runs 74 pages in the Federal Register, is about a megabyte of data. So the Postscript image can give some real compaction and let us play back that perfect document, and it truly is perfect. It's just the way the person who typeset it wanted it to look. I think that the real value of this is that typesetting has meaning. People design type and lay out pages to convey meaning. Bold means something. Italics mean something. Changing font size, footnotes, all of those things have meaning that we tend to lose when we take somebody back to the ASCII text. So the ability to give them that designed image of the document can be very important.

One of the points that I wanted to concentrate on is that we are beginning to try to get federal agencies to look at life cycle management for information and to identify the use and the ultimate archiving and presentation of that information at the same time that they look at data collection and publication. These kinds of technologies I think are a very important part of that because to the extent that we identify up front that we want to archive this document as a Postscript file or in another digitized format and create that at the same time that we create the document, we have the least expensive creation of the digitized image.

It's much more expensive to go back, as Gary McCrone has done and as many other agencies have done, to retroactively convert data, once you've put it on paper and thrown away all of that effort that originally went into the electronic version of it. But to the extent that we could look at that up front and make that a simultaneous action to capture that archival copy, we can move ahead in the preservation cycle on an economic basis.

I can't say strongly enough, however, that standards are absolutely a big issue. We really do need to have standard formats in which to save these documents. Postscript, of course, has become sort of a de facto standard and one that we're using right now for the creation of page images. With the fact that we have a locator coded document, we could eventually regenerate by some other standard if we needed to or convert if some other standard came to the forefront. But it is very important that we are all focusing on how we want these documents stored, so that we really do allow ourselves to use them in the future and allow the generations that come after us to use them effectively.

Also, we need to encourage the agencies to start thinking about this issue of preservation and storage. They need to request that the data be returned to them in digital form. Right now, when an agency comes in and orders a printing job from us, by and large, what they want is the stack of publications, and they don't ask for the digital form back. They don't want it. If you offer it to them, very often they sort of shake their heads and say, "Well, what do you want me to do with this? Why do I want a magnetic tape or a set of diskettes with this data?"

So, historically, we have thrown away the electronic version. We've preserved it at GPO long enough to be sure that the paper copy was correct and that the agency had accepted the material, and then pitched it. Now we've changed our philosophy, and we're trying to educate our agency customers to change theirs, so that we're recognizing that this electronic information is a treasure chest... that we really should be finding ways to hold onto it in ways that let us know which generation of the document it is and what format it is, so that we can help the agencies reuse that information later and provide it to other people who may come in and want copies of that data.

I'm going to switch for a minute and talk a little about CD-ROM because that's another major activity that GPO is working on. We're working with a number of agencies on the production of CD-ROMs. Images are becoming a more and more common part of that production, again, for a lot of the reasons that I already mentioned. The appearance of the information has significant substantive meaning, not just the underlying words. There are a lot of things, like graphics,

86

forms, formulas, and other kinds of things, where people really do need the image data.

We are working with these agencies to go back and to recapture historical data. Then we work with them to identify means to capture it in the future, so that we don't have to go through that retrospective conversion step. So we can build on the present and store forward.

We're also working in the Depository Library Program with some prototypes this coming year for scanned image CD-ROMs. We have an authority in the Depository Library Program to ride orders as they're printed by GPO and purchase our own copies for dissemination. We also have authority, where it's economically feasible or more desirable than printing, to do our own microfiche copies. GPO doesn't normally publish. We are not the publisher of most of the data that we distribute. The agency is publishing it; we're merely their service bureau.

So we are now looking, through the Depository Library Program, at mechanisms to replace microfiche, which is now 60 percent of what we sent out to the depository libraries. 60 percent of the documents we send, that was 27 million copies of documents, went out in microform. It's not a user friendly media. It may last forever, but it isn't really a user friendly media.

We're going to be using some Congressional documents to start with, because of our close working relationship with the Congress. We're going to scan those images, which we feel we have the authority to do, comparable to the authority to microform. We create MARC records already for all of those documents for publication in the Monthly Catalog of Government Publications. So we'll use the MARC records as our indexes to the documents. We're expecting at this point that what we're going to use is the GS Search software from the U.S. Geological Survey, which is in the public domain. Because it's developed by the government, we have no royalties to pay and we can keep costs down. We're going to develop a series of CD-ROMs, taking some of the documents, probably starting with Congressional reports, and distribute them to the depositories and let them compare the use of CD-ROMs to their use of microfiche. We think they're going to get a higher quality print image than they're getting off the microfiche, and we think that the retrieval with the search capability will be far better than the kinds of finding aids and hunt and peck methods that are being used currently with the vast microfiche holdings that we're sending to them.

I've only touched today on a very few of the things that we're doing at GPO, but I was hoping that it would give you at least some idea of the areas that we're beginning to explore and, as you all go back to your own organizations carrying your preservation mission, that you can begin to carry some of this kind of information back to the original publishers and the printing officers and the others in your agency who are involved in the generation of information. Because I think all of you who are tied into preservation recognize far better than the people who are on the generation end, the difficulties of making those decisions after the fact. I think to the extent that we can influence up front a lot of that decision making process, your job is made easier and the value of that information to the public is preserved at a really reasonable cost. GPO would certainly like to be a partner with you in taking that message back and working on mechanisms and standards that would let us design it in up front, capture it the first time, and let that be the one time we capture it, so we can use it through the whole life of the publication.

Judith C. Russell is the Director for Library Programs Service and the Director of the Office of Electronic Information Dissemination Services for the U.S. Government Printing Office. Before joining the Federal Government, she worked in the information industry for nearly 15 years, most recently with Mead Data Central.

Between 1977 and 1988, Russell worked with the Disclosure Information Group, the Information Industry Association and the Information Technology Group. She also managed her own consulting business. Russell's industry experience includes the publication of reference books, CD-ROM applications and microforms, and the dissemination of online information services.

She spent over 10 years as a special librarian with the Congressional Office of Technology Assessment, the Innovation Information and Analysis Project at George Washington University, and COMSAT Laboratories.

Russell holds a bachelor's degree from Dunbarton College of the Holy Cross and a master's degree in library science from Catholic University of America. In addition to her participation in a number of organizations representing the information industry and libraries, she served a term on the Depository Library Council to the Public Printer from 1987 to 1990.

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Electronic Bulletin Board Service Now Available For GPO Deposit Account Customers . . .

The Federal Bulletin Board

To improve access to government information for GPO Deposit Account customers, the U.S. Government Printing Office is now offering **The Federal Bulletin Board**. Using the electronic bulletin board service (BBS) gives you:

-**Immediate, self-service access** to government information in electronic form at reasonable rates.

-**Direct ordering** capabilities for all GPO electronic sales items through the free E-Mail service.

-**Rapid retrieval** of product announcements, subject bibliographies and other free bulletins.

The Federal Bulletin Board software offers all of the most popular BBS features, including:

-**Electronic File Transfer:** Electronic files from a variety of Federal agencies organized by topic heading. You can browse the file lists, review file descriptions, and transfer selected files to your own personal computer, quickly and easily. Although full-text searching of the file contents is not available, you can search by file name, date, and keywords.

-**E-Mail**: Electronic Mail service for ordering products and communicating with GPO. As an alternative to downloading files, you can use E-Mail to order files sent to you on personal computer diskettes. You also can use E-Mail to place orders for CD-ROM products if you already have the GPO stock number.

-**Special Interest Group (SIG) Bulletins:** Open messages to all BBS users, grouped by topic. The SIGs will provide information on products available from the BBS as well as announcements of popular print and CD-ROM publications.

If you have a personal computer, a modem, telecommunications software and a telephone line, you can access **The Federal Bulletin Board** today by calling the BBS at (202) 512-1387. Your GPO Deposit Account Number is your user identification number. Be sure to have your account number and billing address available when you call the BBS. You can use the free BBS services immediately. Other services will be available after your Deposit Account number has been verified. This usually requires 48 hours.

(Announcement mailed to GPO Deposit Account Customers, September 1, 1992.)

GPO provides user support for **The Federal Bulletin Board** through:

- **E-Mail** communication directly to the BBS system operator.
- **Telephone Help** service on weekdays between 8:00 a.m. and 4:00 p.m. EST.
- **User Manual** available for downloading from the BBS, free of charge.

In addition, bulletins on how to use the BBS, new software features, and upcoming BBS enhancements will be available in the **HELLO SIG**.

Charges for **The Federal Bulletin Board** are based on the size of the file downloaded or displayed on the screen. The minimum charge is $2 per file and applies to files up to 50 Kilobytes (50KB). Prices increase in dollar increments, with a full megabyte (1MB) file costing $21. The average file price for currently available material is $6 to $7. The price for transferring a file will be clearly shown on the BBS and daily charges will be reported on your monthly Deposit Account statement. Users are responsible for their own telecommunication charges.

Free services available through **The Federal Bulletin Board** include:

- Using **E-Mail** and **SIG** services.
- **Browsing** file lists and **searching** keyword terms.
- Downloading copies of **instructional** and **product description** files.

Titles Available on The Federal Bulletin Board as of September 1, 1992

The titles listed below should be available on the BBS by September 1. Watch the BBS for announcements of additional files and new Federal agency participants.

Department of Energy: Historical Monthly Energy Review (11 files)
Monthly Energy Review Database; May 1992 (8 files)
State Energy Data System (SEDS) 1960-90 (109 files)
State Energy Price & Expenditure Data (113 files)

Department of State:
Background Notes (Various Countries)
Daily Press Briefings (50 files)
Dispatch (52 files)

EnvironmentalProtection Agency:

Federal Register, Aug. 21, 1992, Part III; Worker Protection Standard; Final and Proposed Rules (2 files)

Toxic Release Inventory, 1990 (63 files)

For additional information about **The Federal Bulletin Board**, contact the GPO Office of Electronic Information Dissemination Services (EIDS) by telephone at (202) 512-1524 or by Fax at (202) 512-1262.

August 27, 1992

The Federal Bulletin Board

GPO Electronic Bulletin Board Service for Federal Agencies

An electronic bulletin board system (BBS) was first established at GPO in 1990 to support the HERMES project of the United States Supreme Court. Under this cooperative project, the Supreme Court transmits slip opinions to GPO and several other organizations for redissemination . At GPO, the Slip Opinion files are reformatted and placed on a BBS for access by the Federal Depository Libraries. The BBS is also used for electronic administrative communications with the Depository community.

This BBS is now being expanded to include **The Federal Bulletin Board**, a new service through which a variety of agency data files will be sold to the general public.

The Federal Bulletin Board software supports most of the functions available on popular bulletin boards. Logically separate views of the BBS can be created, so that publishing agencies, depository libraries and the general public view and access different areas of the BBS. Some of the key features include:

-**E-Mail:** Electronic mail service for GPO, publishing agencies and BBS customers.
-**Special Interest Group (SIG) Bulletin Service:** Open bulletins for general review, grouped by topic. Each publishing agency will have a SIG to announce publication schedules and provide other product-related information to the BBS customers.
-**File System:** Data files organized by topic heading for browsing and downloading by customers and uploading by GPO and publishing agencies.

The Federal Bulletin Board does not support full text searching of the data files. Users can search file names, dates and up to 10 keywords assigned to each file by the publishing agency or GPO.

The Federal Bulletin Board is priced to encourage use. Customer pricing is based on the size of the files downloaded or displayed on the screen. The minimum charge is $2 per file and applies to files up to 50KB. Prices increase in dollar increments with a full megabyte (1MB) file costing $21. The average file price for the currently available material is $6 to $7. Use of the **E-Mail** and **SIG** services is free. Browsing the **File** service is free, as are downloaded copies of instructional and product description files. The users are responsible for their own telecommunications charges.

Initially, payment will be through a GPO Deposit Account. BBS customers who do not currently have a GPO Deposit Account can open one with a major credit card. A $50 deposit is required to open an account, but no minimum balance is required thereafter. There is no fee to establish or maintain an account on the BBS.

(Handout for Federal Agencies seeking information on The Federal Bulletin Board.)

The Federal Bulletin Board offers publishing agencies the following services:

-**Product Acquisition:** Agencies have the option of uploading files directly to the BBS as an alternative to physically shipping source information to GPO. The agency can also use the BBS to leave GPO instructions on what to do with the files prior to their release to the public portion of the BBS. Options include regeneration in other formats, such as ASCII and PostScript. Estimates for conversion costs will be provided.

-**Product Availability:** Upon receipt of product files and instructions, GPO will process the agency's request, mount files on the BBS and support demand reproduction ordered by users. The publishing agency will control the release date and can specify the date that files should be removed from active dissemination.

-**Product Sales and Distribution:** Using a variety of BBS features, customers can download files or place orders for demand reproduction on personal computer diskettes. All files available on the BBS will automatically be available for demand reproduction for customers who cannot or do not wish to download the data from the BBS. In addition, customers will be able to order reproduction through demand printing by GPO for PostScript and other appropriate files.

-**User Support and Documentation:** GPO will provide user support and documentation for the BBS. In addition, agencies may choose to use the **E-Mail** and **SIG** services to provide additional product-related information to customers.

The Federal Bulletin Board runs on a 30486 ISA personal computer with nearly a gigabyte of hard disk storage. Additional equipment will be added as needed.

The software and telecommunications hardware are both supplied by Galacticomm. There are 16 telephone lines with attendant 9600 baud modems which can handle most state-of-the-art asynchronous, acoustic telecommunications. The fastest effective transfer rate hovers at about 750 characters per second. Funding for 32 additional lines will be available October 1, 1992. An additional 32 lines have been budgeted in FY 1994. Modems and lines can be acquired on an accelerated schedule if system usage justifies it.

For additional information on **The Federal Bulletin Board** and how it can support your agency's electronic information dissemination programs, please contact the Office of Electronic Information Dissemination Services (EIDS) at the U.S. Government Printing Office on (202) 512-1524.

September 29, 1992

SESSION III

ENVIRONMENTAL EFFECTS;

MASS PRESERVATION

NATIONAL ARCHIVES PRESERVATION RESEARCH PRIORITIES: SUMMARY AND UPDATE

LEWIS J. BELLARDO, *NATIONAL ARCHIVES*

Most recent National Archives preservation research and development activities at NARA have been reported in Technical Information Paper No. 7, entitled *National Archives Preservation Research Priorities: Past and Present*. Published in 1990 this "TIP" still adequately reflects the research and development work at the National Archives. It is available through the National Technical Information Service as PB90-206210. My remarks today will summarize recent research reported in the research and development TIP, and will note developments since the TIP was drafted.

CURRENT RESEARCH PRIORITIES:

The National Archives is focusing its efforts on a number of research, testing, and development projects. Some are being carried out at the National Archives itself; others involve work on contract or cooperative research among two or more institutions. The National Archives is also monitoring the work of others. This paper groups the projects and areas of research interest broadly into the categories of paper-based and non-paper-based materials, but does not set out priorities or attempt to rank the projects by importance.

The directions of research at the National Archives have been in part conditioned by the needs of our holdings and our overall mission; in part by the major undertaking of planning a new archival facility and preparing records for the move to that facility; and in part by research at other institutions. The decision to undertake work in-house, to contract-out research, or to monitor is dependent upon the availability of resources, staff expertise, and required equipment. The pace of the work in the past two years has been heavily dependent on resource availability and on the challenges relating to our new facility, which we have called Archives II.

RESEARCH ON PAPER-BASED MATERIALS

1. 20 Year Preservation Plan. In the seven plus years since issuing the National Archives 20 year preservation plan, NARA has been working steadily on its implementation. The development of the Archival Information System (AIS) and other automated management tools over the next three years will make possible additional planning tools. Current automation plans call for capturing data on records use, intrinsic value, condition, and preservation actions, and integrating that data into a modeling system for setting and scheduling preservation priorities. In preparation for that capability, the agency is preparing a series of basic documents outlining the components of archival preservation programs and strategies for preserving various media. The next step will be to review existing priorities and to recommend future directions for the agency's preservation program.

2. Microenvironments / Shrink Wrapping. Archival records are housed in many ways. They can exist in bound volumes, in folders inside document boxes or filing cabinets, in display cases, in map cases, in shrink wrap packages, or even loose in drawers or on shelves. The housing is designed primarily to protect the records; however, in so doing, the housing defines the microenvironment in which the records exist. The National Archives seeks to better understand the microenvironments that different housings create, and the effect these have on the housed records.

Shrink wrapping is a case with practical implications for the National Archives. The construction of Archives II will be followed by the move of hundreds of thousands of fragile bound volumes beginning in December, 1993. The National Archives has selected shrink wrapping as a cost-effective measure for packaging and protecting these volumes and safeguarding identifying information during the move. NARA has been involved with research relating to shrink wrapping for a number of years. The Research and Testing Laboratory's work in this area was initiated to determine whether sealing and storing bound volumes in stable plastic damages textblocks over time. The massive use of shrink packaging for the move has placed a heightened importance on this research.

In the first phase of the shrink wrapping research, sheets of paper that had the desired physical properties were hung in a humid aging oven. Fold endurance, brightness, and viscosity were found to decrease significantly following accelerated aging, although there was no consistent, progressive change in acidity. Additional tests have examined the changes in these properties in paper aged in shrink wrapped, simulated bindings, as well as in paper aged in simulated bindings but not shrink wrapped. Results are currently being tabulated, and a final report will be issued during fiscal year 1993.

Under contract with the National Archives, the National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards, recently completed a report outlining a potential long-term research program on the microenvironment issue. Future research in this area may address the questions of how rapidly temperature and relative humidity inside storage containers are altered with changes in the surrounding air, and whether predictive modeling would be useful in understanding microenvironments. Other issues are what decomposition products are given off by archival materials as they age, and what are the effects of these decomposition products on the archival materials and their housings. Related questions might address how the housings of archival materials affect both the records and the chemical nature of the degradation products, how the housings and records are affected by environmental conditions, and what is the useful life of various housing materials.

NIST has recently provided the National Archives with a draft report relating to the absorption of sulfur-dioxide by archival box board. This report will be issued in final form by early calendar year 1993. The work relates to the interaction of atmospheric pollutants and alkaline buffered box board. Work to date suggests that at high concentrations of sulfur-dioxide, absorption is lower than might be expected. Additional work will be done with oxides of nitrogen. The work thus far has suggested other lines of additional research that the National Archives will pursue with NIST assistance:

Absorption by several box boards of sulfur dioxide at lower concentrations;

Absorption of pollutants by box boards with differing formulations.

Future research might also involve investigations of the part played by the non-cellulosic materials (such as calcium carbonate) in the absorption of pollutant gases by box board, and a baseline study of the absorption of sulfur dioxide in pure cellulose.

3. <u>Evaluating Materials Stability</u>. The NARA Research and Testing Laboratory has for a number of years performed routine quality assurance testing on materials used in housings for archival records. In addition, the lab has evaluated and tested materials to be used in exhibit cases and mountings. One convenient and inexpensive testing technique recently introduced is Oddy testing, which examines the corrosive effects of off-gassing of the material being tested on various metal strips (such as silver, copper, and lead) in a small confined space.

Archives II has provided a number of challenges and opportunities to evaluate materials to be used as finishes, coatings, and sealants on walls, floors, and shelving and other storage furniture. One major outcome of this work was the decision to use powder coatings (fused powder polymer coating) on shelving and other storage furniture to minimize off-gassing. Enamel paint was found, by contrast, to present major off-gassing problems for months and even years. Staff also evaluated various approaches to measuring extremely low levels of atmospheric pollutants (parts per billion), and thus of the effectiveness of HVAC filtration systems.

In order to increase the storage capacity of Archives II, the Archives opted to use compact shelving. Working with the concept of compact shelving, the Archives contracted for two significant research projects. The first dealt with weight bearing characteristics of shelving and other storage furniture. The results of this work enabled the Archives more precisely to set specifications in its procurement solicitations. The second project consisted of a burn test to determine how best to minimize the effects of a fire inside a block of compact shelving. The test indicated that sprinkler systems work best when compact shelving rows are not completely closed. As a result of these tests the National Archives decided to use electrically driven compact shelving that will automatically open at the end of the work day any time that a fire alarm occurs.

4. <u>Protective Housings</u>. Records in NARA custody vary tremendously in format, medium, and size. The construction of Archives II has challenged NARA conservation staff to ensure that these records are adequately housed in time for the move. Conservation staff are busy designing, contracting for, and fabricating housings that will both safeguard the records

during the move and provide lasting housings in the new facility. After the move the Archives will report on knowledge gained during move preparation.

5. Copiers and Toners. The 1990 research priorities TIP discussed work done at the National Archives and The Government Printing Office to evaluate the electrostatic recording process, electrostatic copiers, and toners. One result of that project was a practical quality control "peel" test that can be performed by anyone to determine whether a copier is properly fusing the image onto archival bond paper. In the future, as time and resources are available, the National Archives will evaluate the stability of color electrostatic processes.

6. Image Analysis. In February 1987, after five years of development by the Jet Propulsion Laboratory and the Perkin-Elmer Company and the expenditure of $3.5 million, the National Archives installed a charge coupled device (CCD) camera and image processing system to monitor the physical condition of the U.S. Constitution, the Declaration of Independence, and the Bill of Rights. The system, called the "Charters Monitoring System," can compare the pattern of one image with another base-line image to facilitate the detection of changes in a document over time. The system demonstrates the importance of precision and accuracy in electronic imaging and the importance of repeatable image capture for the scientific analysis of electronically produced images.

Since 1990 NARA has continued its involvement with analytical image processing. The Jet Propulsion Laboratory is currently designing and building a degradation chamber to be used in conjunction with the Charters Monitoring System to conduct accelerated aging tests on various test papers and inks. In addition, there will soon be a major upgrade of the computer hardware and software components of the system. This upgrade will permit more rapid processing of data, and will enable the system to process larger bodies of data than is now possible. Third, the Archives has used the CMS on a limited number of additional important documents. Lastly, the Preservation Advisory Committee of the National Archives and the Conservation Analytical Laboratory of the Smithsonian Institution jointly sponsored in 1992 a meeting of users of analytical image processing systems. The purpose of the meeting was to share information relating to techniques, equipment, and software being used in a wide range of image analysis, including visible black and white and color, x-radiographic, infrared, and neutron activated images. Visualization techniques were also demonstrated.

7. Mass Deacidification. The National Archives remains interested in the emerging processes for carrying out deacidification on a large scale. For the most part the Archives has monitored the work of other institutions in this field. However, during 1989 a large body of materials reflecting the variety found in archival repositories (including a wide range of paper types with a variety of recording processes and media, as well as photographic film, and magnetic tape materials) were selected for treatment and testing. The materials were divided into test and control groups. The test samples underwent diethylzinc mass deacidification. In 1992 as the shrink wrap research neared completion, the Archives began its own evaluation of these DEZ treated materials. Physical comparison of treated and untreated materials has been completed, and a testing schedule for such categories as pH, alkaline reserve, brightness, and fold endurance is being established.

8. Ink and Its Effect on Paper. Since there is a practical archival concern about whether deacidification of records created with iron gall ink changes the visual or chemical characteristics of the documents, the National Archives is aiding the National Gallery of Art in a study on this subject. This work is still in its preliminary stage.

9. Fumigation. As stated in the 1990 TIP, NARA is interested in finding a safe and effective alternative to ethylene oxide fumigation, as well as learning about effects of ethylene oxide and other fumigants on paper and various materials. Possible alternatives to ethylene oxide include Vikane (sulfuryl fluoride), oxygen deprivation, and the use of oxygen scavengers. NARA is not currently engaged in research in this area. Rather, staff are monitoring the work of other institutions, such as the Getty Conservation Institute, the Canadian Conservation Institute, and the Smithsonian Institution.

10. Encapsulation. The practice of encapsulating records in polyester film in widespread. Many questions are unanswered, however, concerning techniques, materials, and conditions for encapsulation, and what effect each of these factors has on the way records age. The National Archives research agenda relating to encapsulation is confined to monitoring the work of other institutions, such as the Library of Congress.

11. Paper Strengthening. This is another area where the National Archives is monitoring the research of others. NARA is interested in learning from the work of institutions that are actively studying the

feasibility of impregnating paper with a chemical that either reacts with the paper or with itself to impart strength to the paper. Such a non-destructive mass process would likely be less expensive than single sheet encapsulation or other treatments used to provide support to paper and is, therefore, very attractive to archives and libraries.

RESEARCH ON NON-PAPER-BASED MATERIALS

1. Film and Tape Stability. The stability of polyester-based recording media, specifically photographic film and magnetic tape, has been an ongoing concern of the National Archives. Since 1980, the National Archives has been funding research at NIST into the aging characteristics of plastics. Results described in an interim report indicate that polyester film, which supports the information-bearing material of both photographic film and magnetic tape, could last up to 1000 years if stored at 20-25 degrees Celsius and a relative humidity of 50 percent. Many years of actual experience exist with silver-gelatin photographic film; so the photographic system with polyester substrate is expected to have a long lifetime, given adequate care. Magnetic tapes, however, all hold their information in a layer of magnetic particles dispersed in a crosslinked polyurenthane that adheres to the polyester substrate. Polyurethanes are known to be unstable under certain conditions, especially high relative humidity, so there is concern that these tapes may deteriorate. NIST has also worked on the development of a test method for evaluating tape degradation. Results of the NIST research are reported in an article by Leslie E. Smith in *Restaurator* published in 1991 called "Factors Governing the Long-term Stability of Polyester-based Recording Media".

An additional area of interest for the National Archives is the stability of tapes that employ metal particles in the recording surface. Metal particle tape is coming into increasing use due to its capacity for higher information density and its superior performance characteristics. The National Archives seeks to encourage and monitor research in this area.

The National Historical Publications and Records Commission (NHPRC) of the National Archives provided partial funding to the Image Permanence Institute (IPI), Rochester, NY, to study the degradation of cellulose acetate safety film. The project studied the role of temperature and humidity in the deterioration of cellulose acetate photographic films in use from the 1930's to the present. This work is now complete and a final report is available from IPI and NEH. An additional research project, funded by the National Endowment for the Humanities (NEH) is now in progress.

2. Post-production Processes to Improve Film Life. Over the years, a great deal of concern has been generated over "measles" or redox blemishes on microfilm. Post-production processes have been developed to prevent the formation and growth of microfilm blemishes through protective toning treatments. The National Archives through the NHPRC and the NEH have jointly provided funding to the Image Permanence Institute to continue research into the use of sulfiding treatment to protect microfilm, negative duplicating film, and archival prints against this oxidative deterioration. A report of the first phase of this work relating to newly produced film is now available from IPI and NEH. A second phase of the research funded by the NEH will look at the viability of sulfide treatment for older film.

3. Deterioration of Glass Plate Negatives. Deterioration of 19th century glass plate negatives is a problem faced by many institutions. There is ongoing research to identify the nature and causes of deterioration and to develop methods for arresting the degradation. Research at the National Archives has drawn attention to the particular needs and preservation issues associated with negatives produced on unstable 19th century glass. An article reporting on research in this area and the preservation of these materials at NARA appeared in the Spring 1991 issue of the *Journal of the American Institute for Conservation* (McCabe, C. "Preservation of 19th Century Negatives in the National Archives. *JAIC*, 1991, 30:41-73.)

Related to the issues of unstable glass negative supports, NARA staff conducted a study of the effects of decreasing humidity on glass plate negatives. The results of the study suggested that very low humidity levels (especially levels below 30 percent may cause delamination of the emulsion. An article reporting on this research appeared in 1991 (Constance McCabe, "Glass Plate Negatives: The Importance of Relative Humidity in Storage," *Sauvegarde et Conservation des Photographies, Dessins, Imprimes et Manuscripts; Actes des Journees Internationales d'Etudes de L'ARSA*, 30 Sept. - 4 Oct., 1991, pp. 36-44). Additional work should be done on polyester and cellulose acetate based film negatives.

4. Photographic Activity Test. In conjunction with rehousing of National Archives photographic

holdings NARA has performed numerous photographic activity tests (PATs) as described in ANSI PH1.53.1986. The tests were used to determine the suitability of papers, seamed negative jackets, and paperboards for use as storage enclosures for photographs. In 1988, ANSI adopted a new, more sensitive test, as described in ASNI IT9.2-1988. NARA staff members are currently working with other interested parties to further improve this test. As noted in the 1990 TIP, the National Archives remains interested in developing a test that determines the suitability of various plastics as enclosures for photographic archives.

5. Still Photo Cellulose Acetate Negative Duplication. It has been clearly established in recent years that diacetate and triacetate film bases are not nearly as stable as was once thought. Many negatives in the holdings of the National Archives have shown symptoms of the so-called vinegar syndrome, including shrinking, buckling, and curling of the film base, as well as off-gassing of acetic acid that can damage other film stored in close proximity. As with other institutions with large holdings of these vulnerable materials, NARA has been interested in developing high volume preservation reformatting techniques based on the system developed in the early 1980's by the Washington State Archives which uses 35mm film and a camera system.

Since 1989 at NARA, photo conservators, photo preservation specialists, and photographers have worked to develop a large-format, polyester base, roll film duplication system. The NARA system uses a five inch roll format camera. Since 1990 at least one private laboratory (Photo Preservation Services in Alexandria, VA), and the Library of Congress have set up similar camera duplication systems. At NARA, the interpositives will receive sulfide toning in conjunction with traditional processing. The National Archives has conducted a successful pilot of the system, and hopes to be in full production by January, 1993.

6. Duplication Techniques for Deteriorated Microfilm. The National Archives has recently encountered sizable quantities of accessioned acetate base microfilm that have deteriorated to the point that it is not possible to duplicate the film using traditional printing equipment. Staff have developed a variety of techniques that are effective with the vast majority of the film encountered. The National Archives has as a high priority the creation of polyester base preservation copies of this microfilm. These preservation copies will be stored under environmental conditions that should safeguard the film for several centuries.

7. Polyester Base Motion Picture Film Pilot. Motion picture film is the last major form of photographic film to move from an acetate to a polyester base. In part this lag has been due to the fact that acetate base film is easier to handle and easier to use on existing printers. In part the lag has been due to the relative difficulty in ordering polyester base motion picture film. There also have been arguments posed by proponents of traditional acetate base film that polyester base motion picture film does not produce a uniformly high quality product. During fiscal year 1993 the National Archives will begin testing various polyester filmstocks. The goal is to be able to switch to polyester base film for all preservation duplication by the end of fiscal year 1993.

8. Other Research on Photographic Materials. There are a number of other areas of research that the National Archives intends to pursue as staffing and/or contracting resources permit. Areas of particular research interest include:

a. the salvaging of water-damaged microfilm, motion picture film, and photographic prints and negatives;

b. the long term effects of photographic storage enclosures as they pertain to the use of polyester sleeves, or buffered vs neutral pH paper enclosures;

c. the development of exhibition standards for photographs in terms of light levels; and

d. the effect of conservation treatment procedures used on photographs.

NARA staff members continue to monitor developments in these areas and conduct research when possible. In particular, NARA staff currently gather data on image changes on photographs before and after exhibition, and staff in the Document Conservation Branch hope soon to initiate research comparing the effects of buffered vs neutral pH paper vs polyester enclosures in the long term aging of photographs.

9. Digital Image Capture and Enhancement. NARA sponsored research in this area was reported by Charles Dollar.

10. Stability of Optical Media. NARA sponsored research in this area was reported by Charles Dollar.

11. Optical Media for Preservation. NARA sponsored research in this area was reported by Charles Dollar.

12. Preservation Policy for Electronic Records. In 1987, the National Archives negotiated an interagency agreement with what is now the National Computer Systems Laboratory of the National Institute of Standards and Technology (NIST). In May 1989, the National Archives received a report from NIST concerning data exchange standards for electronic records. A complementary report on the subject was produced by the National Archives' Archival Research and Evaluation Staff.

The importance of data exchange standards for preservation of electronic records is that records maintained in a standard format are free from dependency upon proprietary software and can be easily transferred between or accessed from conforming systems. Progress in this area is still at a fairly primitive stage. The National Archives will continue its efforts to encourage the development of data exchange standards.

The National Archives' Center for Electronic records has developed strategies for preserving electronic records in the existing world of varied and incompatible systems. First, there is an ongoing effort to recopy tapes every ten years to ensure transportability and to overcome technology obsolescence. Second, the Center has developed an automated tool called the Archival Electronic Records Inspection and Control System (AERIC) to automatically validated tapes when they are accessioned. AERIC will also soon be used to develop a data dictionary to store metadata regarding electronic files being preserved. This function will be of vital importance for preserving relationships in complex database structures. Third, the Center will soon award a contract for the Archival Preservation System (APS). This automated tool will analyze technical aspects of tape files to determine their readability. It will also create standardized file labels, and permit the Center to do in-house preservation copying of tapes.

STANDARDS ACTIVITIES

Staff members of the National Archives participate in a number of standards organizations, and assist in the development of standards relating to the preservation of paper-based, film, magnetic, and optical media. They also are involved in the cooperative testing of materials to further the work of various standards groups. For example, NARA's Research and Testing Laboratory, in conjunction with the subcommittee revising Z39.48-84 on permanent paper, has recently carried out both Kappa tests and light and humid aging of chemithermomechanical papers and semi-bleached papers.

NATIONAL ARCHIVES PRESERVATION RESEARCH PHILOSOPHY

The mission of the archivist is to preserve records and to make them available for use, the mission of the scientist, conservator, and special media preservation specialist is to assist the archivist in achieving these objectives. In developing archival preservation programs, it is necessary to integrate the knowledge and skills that these groups can bring to bear on the preservation problems confronting them. Research, testing, and the development of new techniques are important tools for addressing preservation issues and problems. Whenever possible, the National Archives will promote research into the preservation needs of each new recording medium as soon as it appears that the U.S. Government will make widespread use of it.

In keeping with this philosophical foundation of our preservation research program, the results of National Archives research and testing activities will be reported to the archival, preservation, library, and scientific communities via published reports and written communications. Notices regarding the availability of such reports will be submitted to standard journals and professional society newsletters.

Dr. Lewis J. Bellardo has been Director, Preservation Policy and Services Division, National Archives and Records Administration (NARA) since 1990. He was Director, Center for Legislative Archives at NARA from 1989 to 1990. Prior to working for the National Archives, he was Director, Georgia Historical Society (1986-1989), and State Archivist and Records Administrator, Kentucky (1980-1986).

THE RESEARCH PROGRAM OF THE GETTY CONSERVATION INSTITUTE

JAMES R. DRUZIK, *GETTY CONSERVATION INSTITUTE*

ABSTRACT

The Getty Conservation Institute may be an unknown entity to some and, as part of a California operating trust, it has the unique feature among conservation research and training organizations of being self-funded and, to the extent it wishes to be, self-sufficient. Therefore, the Institute will be briefly described, its research agenda outlined and its perceptions of current and future needs discussed. Dr. Shahani's invitation to this meeting indicated its function clearly. It was, he said, to go beyond technical information exchange, to promote interaction and to forge creative links among participants. I hope this presentation meets that need.

BACKGROUND

The Getty Conservation Institute (GCI) was created in 1983 by the J. Paul Getty Trust as one of seven autonomous operating programs. It seeks to develop, apply, and make available appropriate solutions to conservation problems through research, training, field work, and information exchange. The Getty Conservation Institute contributes to scientific knowledge and professional practice through projects that address preventive and remedial conservation of objects and collections, monuments and sites and historic structures and cities.

The Scientific Program of the GCI is split between its laboratories in Marina del Rey, California and its service laboratory at the J. Paul Getty Museum in Malibu. Altogether approximately fifteen scientists work in Marina del Rey and three at the Museum. Beyond this and depending on the research agenda of any single fiscal year there may be from twenty to eighty scientists and technical support personnel working on contracted research in industry, academia, museums, or at other conservation research institutions.

RESEARCH AREAS OF INTEREST

The first year of the Scientific Program's existence, saw In-house activities largely dedicated to hiring the first staff and purchasing and setting up the first analytical instrumentation. Extramural or outside contracted research tended to be opportunistic and without a true program philosophy or structure. The first four projects were on accelerated aging, a systematic look at cellulose ethers as used in conservation treatment, photochemical oxidants in the museum environment and Japanese lacquer.

In 1985, the Director of the Program, Dr. Frank Preusser and myself began to build a real program. There would be five major areas—the museum environment, conservation materials and methods, new technology, architectural conservation and in-situ archaeological conservation. We later merged architecture and archaeology into a single section and concentrated on these four. For periods of 5-7 years one area would be at the core subsuming half our resources while the other three remained active but carrying less emphasis. The museum environment was this first core program and generated twenty-one projects on outdoor and indoor-generated air pollution, materials damage from pollution, pest control, and selected topics integrating energy conservation and museum design. We identified with "museum environment" because one of our sibling programs was an art museum, but no project applied any less to libraries and archives than to art museums. Figure 1 diagrams the principle components of these first years and every project was carried through to fruition. Architectural conservation replaced this emphasis in 1991.

While the museum environment was paramount, other areas did not suffer neglect. Conservation materials and methods research is represented by some twenty-two projects, architecture and archaeological sites—sixteen, and new technologies—twelve. All seventy-one activities have been documented in a publication entitled *Research Abstracts of the Scientific Program* available from the GCI. We have sponsored three symposia along with CAL under the umbrella of the Materials Research Society entitled "Materials Issues in Art and Archaeology" in which the material sciences of all cultural artifacts are highlighted, including paper. The third edition of this symposium, taking place only a few month ago drew almost 100 papers.

In the early summer of 1992, a major change occurred within the Institute in terms of how it looked

at itself. Programs within the Institute had been somewhat territorial. Now, no longer was the Scientific Program exclusively the single champion of research, nor documentation of the Documentation Program, nor training and education of the Training Program. Programmatic hegemony was broken.

The GCI now defines all its projects, regardless of origin, according to four component functions:

- Research
- Training and Education
- Conservation and Intervention
- Information and Documentation

All GCI projects can be defined by the fields of artifacts they apply to:

- Objects and Collections
- Monuments and Sites
- Structures and Historic Centers

And all GCI projects advocate a philosophy or approach:

- Preventive Conservation
- Disaster Planning
- Appropriate Technology
- Management

It will be interesting to see how this new "order" manifests itself.

DISSEMINATION OF RESEARCH RESULTS

Being a research manager second only to the Director of the Scientific Program in culpability for the allocation of, and influence on tens of millions of dollars of research funding — I'm particularly sensitive to the issues of dissemination to conservators and enhancing utilization of scientific research in the archives and library environment, particularly by decision-makers. This is, in part why GCI keenly encourages and participates in ventures sponsored by the Commission on Preservation and Access, the National Archives and Records Administration, Library of Congress and the National Institute for the Conservation of Cultural Property.

The five most fearful information transfer myths I face daily as a science manager are that:

1.) Mailing a report constitutes communication,
2.) Publications are routinely read by all or even by some,
3.) Reading insures remembering,
4.) There is a relationship between providing scientific information and what is done with that information, and that,
5.) Opinion and fact are readily distinguishable by educated people.

The GCI is aware that technical publications and dependence on the user to find and interpret it (or the "toss it through the transom" approach) is not particularly efficient in getting information to those who need it. Clearly, more efficient venues are needed, including highly focused workshops, short courses, symposia and technology translating or interpreting publications. These venues have sticking power because most of the technical information identified by Cogan and Holt in 1975 as influencing decision-makers has been acquired by these routes.

The failure of communication in conservation research was manifested at the Albuquerque meeting of the American Institute of Conservation in 1991, when Richard Smith stood up in the Paper Specialty Group Meeting and in anguish remarked that the same questions were being raised concerning the merits of deacidification that he had heard twenty years before in a similar forum. In another example, the AIC Conservation Science Task Force compiled over 250 research priorities from conservators. Twenty-five percent of these priorities have been fully addressed in the extant literature. Twenty-five percent have been answered sufficiently to render them low priority, if important at all. Twenty-five percent were not research questions requiring a scientist but more properly comparative work that the conservator could perform. And the remaining one quarter split between bad ideas and issues worthy of future research commitments. This situation probably cannot be modified significantly, but the nature of its existence should be routinely inculcated. This problem is as much the responsibility of the provider as it is the user of this information. Because of this fact, in the current fiscal year, all departments of the GCI have budgeting for the undertaking of a massive outside evaluation of the effectiveness of our individual programs. This, it is hoped, will assist in forging ahead with greater confidence and success.

NEEDS OF THE FUTURE

What do we perceived the needs of the future to be? One approach that might assist in our collective communication problems, would be the establishment of a single national or international archives and library research agenda. By convening a meeting like the present one, the Library of Congress has already taken the first step. If there is still much research that needs to be done, and few would disagree that there is, such a body or a smaller subset might meet several times a year for the next year or two and hammer out such an agenda. The notion would be implicit that these partners would themselves divide up the agenda among themselves. This idea is not unique because it is part of the rationale of this meeting. What we feel is important — is properly and rigorously marketing this union and prioritizing education and information transfer at the same level as any new research.

This serves a number of functions. It begins by coalescing a now diffuse sense of leadership. It also obviates the need for a single monolithic funding agency, which we all know will never magically materialize especially in the current economic climate. And further, it should provide an umbrella for a series of workshops on selected topics of significance to preservation managers and conservators alike.

One other important agenda item should be stressed. *Agreeing upon what we all know.* Thiel [1992] recently remarked on information transfer in the seismic hazard mitigation community

"...that the information available to the community on hazards is so divergent that informed, intelligent individuals can have difficulty in determining what is factual and actionable. These individuals sample the opinion of several consultants (experts or those perceived or presented as experts) compare their content and then reject most of what either says if there are points of disagreement (even if they are in substantial agreement except for a few points) since there is no apparent criterion for choice."

Thiel continues:

"There is a clear and apparent need for the community of scholars to "get its act together," deliver a few simple messages clearly and uniformly, act as a community to increase the public's knowledge of the actions that can moderate hazard occurrence impacts, and reinforce the veracity of those that are knowledgeable."

I submit that this is as relevant to the library and archives preservation community as to hazards reduction and a main concern for all of us.

REFERENCES

Cogan, Holt and Associates 1975. *Housing and Local Government: An Evaluation of Policy-Related Research in the Field of Municipal Housing Services*, Technical Report, New Haven, Connecticut, January 1975.

Thiel, C.C. and J. R. Druzik 1992. "Enhancing Utilization of Scientific Research in the Archives and Library Environment", manuscript in preparation. This paper is an expansion and refinement of: Thiel, C.C. 1988. "Enhancing Utilization," *Proceedings of Conference XLI, Research Applications in the National Earthquake Hazards Reduction Program 1977-1987*, USGS Open File Report 88-13A, Reston Virginia.

James R. Druzik is a conservation scientist at The Getty Conservation Institute, Marina del Rey, California, where he is responsible for coordination, monitoring, and much of the experimental design development of the Institute's network of sponsored contract research. This research falls into the areas of environmental engineering, stabilization of historic architecture and archaeological sites, materials science of art and architecture, and new technologies.

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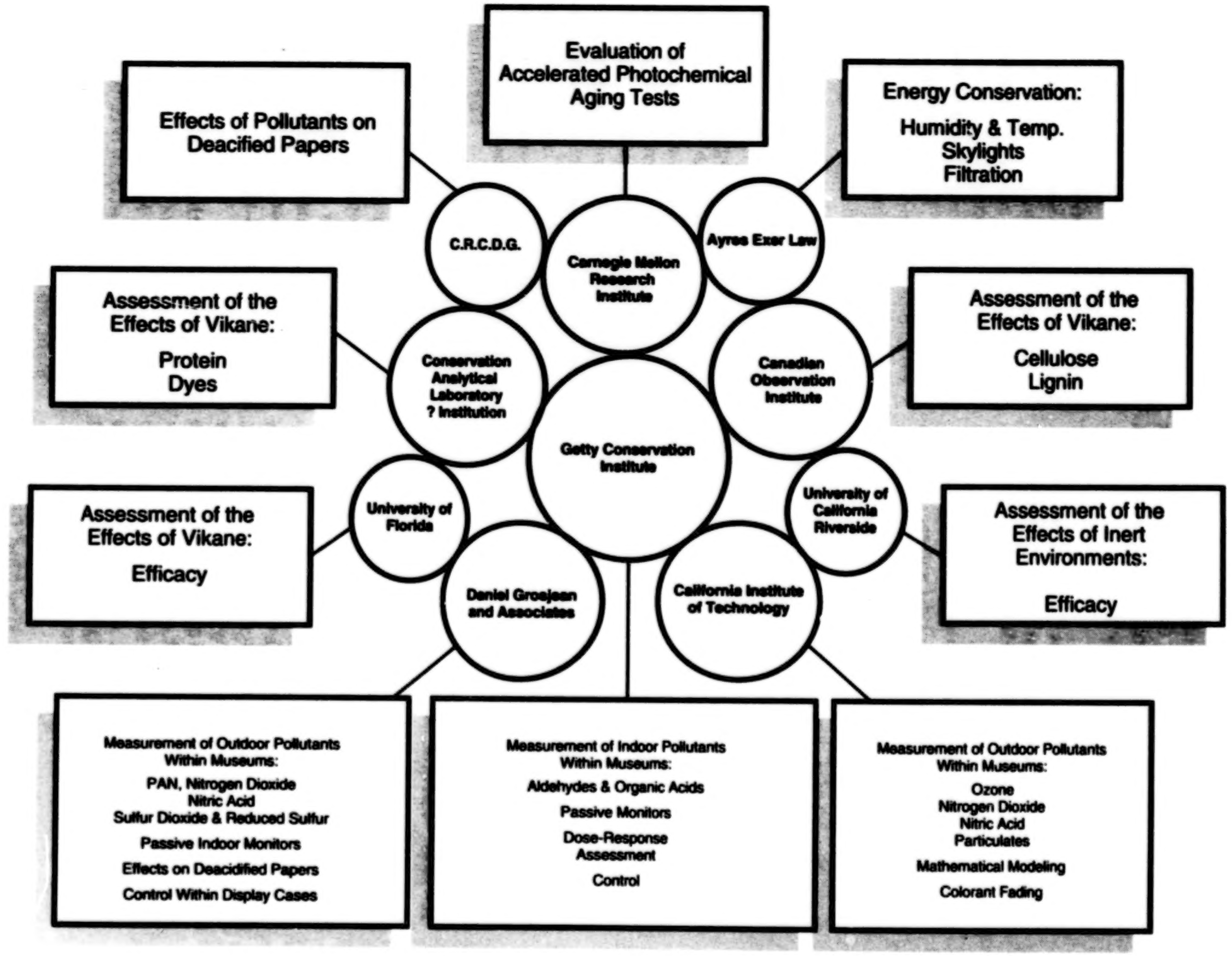
Environmental Research Program



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ARCHIVES AND LIBRARY RELATED RESEARCH OF THE GETTY CONSERVATION INSTITUTE

(Since there are approximately 100 publications associated with these projects, the *Research Abstracts of the Scientific Program (1992)* by James R. Druzik should be consulted for further details.)

Evaluation of Test Procedures for Accelerated Photochemical Aging of Museum and Archival Materials

The Principal Investigator is Robert L. Feller. Laboratory work was begun in 1984 and completed in 1987. The final book publication is scheduled for Spring 1993.

Never before has accelerated photochemical aging of museum and archival materials been evaluated as thoroughly as in the current research package. Regions of the visible and ultraviolet spectrum have been investigated for reactions involving yellowing and bleaching (cellulose and wool); chain-breaking and cross-linking; (Elvacite and poly(vinyl butyral); and effects on fading of temperature and relative humidity.

Potential Adverse Effects of Pest Control Agents on the Materials of Museum Artifacts — CCI

Work carried out by Nancy Binnie and Helen Burgess. Research completed.

Investigation of the potentially harmful interaction between Vikane (Sulfuryl Fluoride) and cellulose, starch and lignin-containing materials. Changes in percent reflectance are reported after accelerated aging at 70°C and 50% relative humidity. Results were also obtained for average degree of polymerization, nitrophenylhydrazone carbonyl content, total acidity (by iodometry); extracted and surface pH, and tensile strength (Instron). The set of exposed samples numbered 25 groups of paper and textile fibers containing cellulosic and ligneous fibers. Similar investigations were undertaken at CAL on pigments and dyes and at the GCI on metals and ploymers.

Feasibility of Using Modified Atmospheres to Control Insect Pests in Museums

Work carried out by Janice Kennedy and Michael Rust at the University of California, Riverside in collaboration with Frank Lambert and James Druzik at the GCI. Research completed.

The primary objective of this study is to determine if the displacement of oxygen by gases such as nitrogen, helium, and carbon dioxide is lethal to insects that infest susceptible antiques, artifacts, and objects displayed, curated or stored in museums. It is possible to produce anoxia and kill these insects, a secondary objective will be to expose the insects inside an assortment of items such as books, tapestries, wooden picture frames, etc. in controlled atmosphere chambers to determine if the presence of these objects effect control.

The project will consist of three phases, Phase I - construction and testing of hermetically sealed cases, Phase II - determining the effect of oxygen displacement on various life stages of important insect pests found in museums, and Phase III - testing of artificially-infested objects and materials. The objective of Phase II will be to determine the potential activity of anoxia against insect pests under clinical or ideal conditions. Physical and chemical factors likely to interfere with optimal activity such as the thickness of wood, paper or cloth will be studied in Phase III. Seven representative insect pest species will be examined in the initial portion of Phase II. These are <u>Thermobia domestica</u> (firebrat - Thysanura), <u>Blattella germanica</u> (German cockroach - Dictyoptera), <u>eriplaneta americana</u> (American cockroach - Dictyoptera), <u>Incisitermes minor</u> (Western drywood termite - Isoptera), <u>Lasioderma serricorne</u> (Cigarette bettle- Coleoptera), <u>Anthrenus flavipes</u> (Furniture carpet beetle - Coleoptera), <u>Tineola bisselliella</u> (Webbing cloths moth - Lepidoptera). If the results are promising, additional important pests species may be included in the study.

Phase I of the study will be conducted at the Getty Conservation Institute (GCI) and at the University of California, Riverside (UCR). Phases II and III will be conducted at UCR because of the large number of insects to be cultured, selected, and observed in each test, the need for controlled temperature chambers to maintain the insect and sealed cases, and the possibility of escape of insects during the rearing and exposure portion of the study.

Protection of Works of Art from Damage Due to Photochemical Smog

Senior project team consisted of Glen R. Cass, Paul M. Whitmore and William W. Nazaroff, Californias Institute of Technology and James Druzik, GCI. Research completed.

The objective of this research program is manyfold including -

- establishment of ozone as a damaging factor to sensitive colorants

- establishment of nitrogen dioxide as a potentially damaging factor to sensitive colorants

- measure indoor ozone, nitrogen dioxide concentrations in a selection of museums and art galleries in the Southern California area

- determine protective strategies shielding sensitive objects physically from exposure

- mathematically model indoor air quality for the museum environment

- determine the protective effects, if any, of a wide assortment of binders and coatings on a broad selection of paint media

- determine as well as possible mechanisms of ozone damage to a few of the larger classes of colorants

- specifically those based on Alizarin and like compounds and the Indigo system.

Protection of Works of Art from Damage Due to Deposition of Airborne Particulate Matter

Senior project team members were Glen R. Cass, William W. Nazaroff, Lynn G. Salmon and Mary P. Ligocki, California Institute of Technology. Research completed.

This project is designed to establish the physical and chemical pathways by which airborne particulate matter acts to damage works of art. Emphasis will be placed on understanding how to break the chain of events leading to the soiling and corrosion of art objects by depositing particulate matter.

Indoor particulate standards have not been established by the Environmental Protection Agency (EPA) or the California Air Resources Board (ARB) in part due to a lack of information on the character and quantity of these materials. The results of this study between the GCI and Caltech, with the participation of five Los Angeles-based museums will establish baseline values for just such standards.

Protection of Works of Art from Damage Due to Atmospheric Nitric Acid

The Principal Investigators are Glen R. Cass and William W. Nazaroff. The research has been completed and the final report is in preparation.

Preliminary tests suggest that nitric acid vapor is capable of inducing rapid fading and color shifts in a variety of important artists' colorants. A study will be pursued to determine whether or not nitric acid at the levels found to be drawn into museums from outdoors is capable of causing damage to the colorants used in works of art. The research effort will consist of several parts. First, chamber studies of the fading and color changes observed in artists' pigments upon exposure to ppb levels of HNO_3 in purified air will be conducted to identify those pigments that are susceptible to HNO_3 damage. An investigation of the chemical mechanisms by which HNO_3 attacks these susceptible colorants will be conducted to confirm that HNO_3 is indeed responsible for the observed color changes. Existing experimental data on indoor and outdoor HNO_3 levels measured in five Los Angeles area museums will be evaluated to determine the HNO_3 flux to museum collection surfaces over time. Finally, advice will be provided on methods for protecting museum collections from damage due to HNO_3 vapor exposure.

Museum Survey of Indoor PAN, Nitrogen Dioxide, Nitric Acid, Chlorinated Hydrocarbons, Sulfur Dioxide and Total Reduced Sulfur

Daniel Grosjean and Associates have been the principal contractors. Research was completed.

Peroxyacetyl nitrate (PAN), nitric acid (HNO_3), and chlorinated hydrocarbons have never been monitored indoors. Nitrogen dioxide, sulfur dioxide and total reduced sulfur have been measured but only in a few museum environments. Since all four pollutants have serious materials damage potential, they will be surveyed. Nitrogen dioxide will be the subject of a larger survey planned in the future since it is known

to be more universally distributed both nationally and internationally than the other three pollutants.

Air Pollution Control within Museum Display Cases by Active and Passive Sorbent Strategies

Daniel Groajean and Associates have been the principal contractors. Research is completed.

The objective of this study, which is deemed to be very important, is to provide the art conservation community with simple and cost-effective methods for reducing environmental damage to objects of art exhibited in display cases. To achieve this objective, a large matrix of experiments will be carried out to test the effectiveness of selected sorbent materials for the removal of pollutant gases.

The pollutants examined are SO_2, NO_2, H_2S, O_3, and HCHO both in a passive mode, i.e. as a static flat bed, or in an active mode, i.e. pumped through a packed bed of sorbent.

Study of the Effects of Sulfur Dioxide and Nitrogen Dioxide on Deacidified Papers Part 2

Daniel Groajean and Associates have been the principal contractors. Research is completed.

HPLC was used for bulk extraction analysis of the anionic content of all paper samples. Both deacidified and untreated paper samples absorbed SO_2 and NO_2 throughout the exposures. Most of the absorbed SO_2 was accounted for as sulfate (65 +-30%). No sulfite or bisulfite was detected. Absorbed NO_2 was accounted for as nitrite and nitrate within experimental error. Paper samples absorbed more SO_2 than NO_2. Deacidified paper absorbed more SO_2 than untreated paper. Paper absorbed less SO_2 and NO_2 over time whether exposed singlely or together. After 40 days of exposure to NO_2 or NO_2 + SO_2 the paper samples were only removing 10 +-10% of the inlet NO_2 concentration. Whereas it took nearly 29 weeks of exposure to SO_2 for the removal of the inlet SO_2 concentration to reduce to 10 +-10%. All observations made in this study are for the specific type of newspaper and white wove paper we used and caution must be used in extrapolating our results to other types of newsprint and white wove paper. Electron spectroscopy for chemical analysis, ESCA, was used to analyze the surface of several unextracted paper samples for sulfate, bisulfate, sulfur. nitrate, nitrite, nitrogen, carbonate, carbon, oxygen and metals. No detectable nitrogen or carbonate was found.

Development of Passive Monitors for Museum Air Quality Measurements

Daniel Grosjean and Associates and Dusan Stulik and Cecily Grzywacz from the GCI were the project team. Research completed.

The measurement of air pollutants including indoor aldehydes, is currently limited in two ways. Analytical methods capable of measurement in the parts-per-billion range require considerable technical skill and equipment, which places these outside the range of most institutions. The second limitation is that current passive monitors were designed for human health monitoring and are 100-1000 times less sensitive than the concentration ranges often found in museums. For these two reasons, the development of a more sensitive passive monitors will be implemented in two phases. Phase one includes three steps, (a) to evaluate present methods for formaldehyde monitoring including passive and analytical methods, (b) develop new monitors based upon the most promising methods, and (c) test and field validate these new devices in selected museum settings.

Phase two continues with formaldehyde exploring direct-reading badges, and includes ozone, nitrogen dioxide, PAN, total oxidants and sulfur dioxide.

As a result of phase one, completed winter 1989, one commercial monitor has been identified to have reliable ppb monitoring capabilities based upon the DNPH method. This monitor is available from GMD Systems, Inc. (Hendersonville, PA) at a cost of $10.00 for the badge and $40.00 for prepaid analysis. Phase one has also resulted in an alternative badge design than has been well characterized and will be utilized during subsequent specific-pollutant monitor development in phase two.

When these passive monitoring methodologies have been finished they shall be included within a global network monitoring program currently under design.

Energy Conservation and Climate Control in Museums

The Project Team was J. Marx Ayres, J. Carlos

Haiad, Henry Lau, Ayers Ezer Lau, Consulting Engineers, and James R. Druzik, the GCI. Research completed.

A team composed of a mechanical engineering fellow, experienced mechanical engineers, and conservators will develop a methodology for carrying out environmental surveys/case studies that will bring together the experiences which have evolved from the last 15 years of museum construction. A small number of target museums will be studied intensively in this phase of the study, in order to perfect the survey methodology, and to define more precisely the future development of the project. The primary mechanical engineer who will serve as consultant to the project is Marx Ayres.

What this study has shown is that with a modern, heating, ventilating, and air conditioning (HVAC) system in a typical small museum, the least expensive relative humidit y; to maintain is 50% with significant cost increases resulting in trying to maintain higher and lower average humidity levels. The different energy costs associated with controlling the relative humidity within +-2% to +-7%, are not significant within those limits, and therefore humidity control should be based upon the limitations of available equipment, combined with any unique requirements of the collection, if any. While it intuitively seemed possible that maintaining higher summer or lower winter temperatures might lead to reduced energy costs, the small temperature variations, consistent with keeping collections, staff and patrons comfortable and happy, resulted in only 1-3% savings in the combined cooling, heating, and humidification loads.; This contrasts drastically when compared with the potential savings that can be realized in where heat recovery chillers could save 88-99% of the heating and humidification costs. Heat recovery chillers being just one of an array of possible energy-saving strategies that could have been simulated.

Energy Conservation in Museums: Skylights, Filtration, Condensation, Infiltration/Pressurization, Vestibules and Outdoor Air Control

The Project Team was J. Marx Ayres, J. Carlos Haiad, Henry Lau, Ayers Ezer Lau, Consulting Engineers, and James R. Druzik, the GCI. Research completed.

This project has six main tasks:

(1) Provide additional DOE-2 simulations to determine the cost sensitivity of various particulate and activated carbon filters located within the HVAC system at one location.

(2) Provide additional DOE-2 simulations to determine the cost sensitivity of various sized skylights in five locations: Burbank (California), Albuquerque (New Mexico), Minneapolis (Minnesota), New York (New York), and New Orleans (Louisiana).

(3) Demonstrate the use of the Dew Point Profile Method for predicting regions of condensation within a building.

(4) In previous simulations, it was assumed that the building was pressurized and there was no infiltration. This assumption is valid for most buildings, but requires closer evaluation in tall buildings subject to stack effect, buildings with severe wind exposures, and buildings with high traffic rates. This topic is revisited for buildings with infiltration.

(5) In main source of infiltration for newly constructed buildings is through entrance doors. What mitigation is offered by vestibules?

(6) How can one assure minimum ventilation rates consistant with the latest ASHRAE standards?

The Scott Gallery of the Huntington Library and Art Gallery in San Marino California will be the modeled building.

Museum Survey for Indoor Aldehydes, Ketones, and Organic Acids

Principal Investigator is Cecily Grzywacz, the GCI. Research in progress.

For some decades now carbonyl compounds and organic acids have been recognized in the museum world as corrosive agents for lead objects, leaded bronzes, ethnographic objects, and a variety of other materials. These pollutants can be generated from materials used in storage areas and in the construction of display cases, such as particle board. Measurements have been sporadic and not quantitative. This was mainly due to the lack of an appropriate and accurate technique for the determination of low concentrations (part per billion) of these pollutants. The technical development of High Performance Liquid Chromatography has provided a method for the mea-

surement of these pollutants at the ppb level.

This research activity is designed to monitor the concentrations of carbonyl compounds and organic acids in a series of museum in Southern California, in display cases, open galleries, and storage. The following trends were determined. For [formic acid], the majority of sites (95%) had concentrations less than 5 parts per billion (ppb), 12 fall between 5-10 ppb, and only 6 had concentration greater than 10 ppb. For [acetic acid], 80% of the samples taken were less than 10 ppb. For [formaldehyde], the spread was greater but still, 80% fell below 10 ppb. And lastly, for [acetaldehyde], 89% of the case showed concentrations less than 10 ppb. For these values the trends were that concentrations followed the following order: display cases > storage > galleries.

Feasibility of a Global Network to Monitor the Exposure of Cultural Properties to Environmental Stresses

Principal Investigators would be Glen R. Cass and Daniel Grosjean. Proposed Research.

On a number of occasions, The Getty Conservation Institute's (GCI) efforts to conserve architectural sites and museum collections have led to requests that environmental assessments be conducted. Exposure assessments are often requested because little data exist on an international or global scale that can be used to estimate the likely hazard when cultural properties are exposed to environmental stresses.

With the recent development of new sensitive and cost-effective passive monitoring methods, it appears possible to establish a worldwide monitoring network to economically assess the exposure of cultural properties on a global scale. This global monitoring network would be based on passive monitors and on the assumption that cultural site managers and museum officials around the world would be willing to cooperate to the extent of placing a simple passive monitoring package at their site and return it to California.

If this can be done, it would be a major accomplishment—the first global monitoring program to simultaneously acquire data on levels of damaging air pollutants, soiling rates and light fading hazards using identical methods at all sites. Accurate comparisons of exposure risk at different cultural heritage sites could be made. Warnings could be issued to managers of sites where severe conditions are observed. Research at GCI on matters of protection of materials from damage due to air pollution could be targeted to the locations where those results are most needed. Follow-up studies could be aimed at areas where the greatest risk of accumulated damage is present.

Since the concept of a global passive monitoring network is entirely novel, the first step must be to undertake a feasibility study to explore whether or not such a program could in fact be implemented. This feasibility study is the object of this project, which addresses the issues of network design, passive monitoring technology, selection of parameters to be combined into a passive sensor unit, "pilot-scale" field trials, logistical aspects, time schedule and cost estimates.

Evaluation of Cellulose Ethers and Certain Water-Soluble Synthetic Polymers as Coatings For Conservation Application

Project Team was Robert L. Feller, M. Wilt and John Bogaard, Mellon Institute. Research completed.

Cellulose ethers have been used for some time in several branches of conservation, but no systematic study of their permanence or durability has been conducted. This current study concentrates on seven classes of cellulose ethers—carboxymethylcellulose, methylcellulose, ethylcellulose, ethylhydroxyethyl-cellulose, hydroxypropylcellulose, poly(vinylalcohol), polyacrylamide, and poly(vinylbutyral), These classes have been evaluated in terms of their thermal, photochemical, and hydrolytic stability. Samples were prepared as powders and as films — with and without a backing material— and subjected to controlled exposures of heat and light. At selected intervals during the experiment, samples were removed and tested for changes in polymer chain length, weight loss, embrittlement, discoloration, peroxide formation, and decreases in solubility.

All these tests taken together provided a relative ranking of these materials in terms of their potential durability in conservation applications. Carboxymethylcellulose and methyl-cellulose proved to be the most stable, followed by ethylhydroxyethylcellulose and hydroxypropylcellulose.

Although accelerated aging tests were used to obtain relative characteristics of the various coatings, an effort was also made to estimate their potential

long-term stability under normal conditions. Some organic soluble cellulose ethers were found to deteriorate so rapidly that they were not recommended for use in conservation, but in general, early estimates of lifetimes of the water-soluble types under normal museum conditions ranged from 42 to 100 years.

Aqueous Light Bleaching of Paper

Project Team is Terry S. Schaffer and Victoria Blyth Hill, Los Angeles County Museum of Art and James R. Druzik, the GCI. Research in progress.

This collaborative project between LACMA and the GCI will undertake to provide a detailed description of the effects of aqueous light bleaching on the changes in paper properties caused by subsequent aging. In particular, attention will be given to rag paper samples which have been pre-aged under conditions chosen to create degradation typical of that faced by conservators. The effects of aqueous light bleaching will be monitored by measurement of gross chemical alterations in paper components and of changes in color and strength of the sample papers, after control and experimental treatments, and after post-treatment artificial aging.

Treatment conditions for the aqueous light bleaching step will closely parallel those used by practicing conservators. Initially, experiments will be performed to determine how variations in some experimental conditions influence the results of the treatment. Conditions which optimize results will be selected for use in subsequent studies, for which they will be carefully controlled.

Moisture Buffering Capability of Museum Storage Cases

Principal Investigators are Vinod Daniel and Shin Maekawa, the GCI. Research completed.

At the request of the Getty Center in 1988, the effectiveness of Solander boxes to buffer changes in the environment was investigated. The results indicate large variation among the boxes in their hygrometric half-lives, the time required for the microenvironment inside the Solander box to reach half the relative humidity (RH) value between the initial RH of the inside and the RH of the environment. The effectiveness of matte boards in the Solander boxes to buffer changes of the environmental RH were also measured, and a marginal improvement over the empty box was observed in a higher RH environment. However, a significant added protection was noted in a lower RH environment. Future work will involve the study of different types of museum and library storage cases and the effects of periodic changes of environmental RH and temperature.

Collaborative Research in Scientific Image Documentation and Analysis (CRESSIDA)

Current Project Team is Kathleen McDonnell, Barbara Snyder and James R. Druzik, the GCI; Henry Lie, Fogg Art Museum; Alan Newman, Frank Zuccari, and William Leisher, The Art Institute of Chicago; David Saunders, The National Gallery, U.K. Research has just begun.

The use of digital image processing in conservation has become a practical reality. No longer are mainframes or powerful minicomputers required along with their required support personnel. While these devices will still be used for high level research and applications development by the largest of public institutions, low end microcomputers and the current generation of imaging software that runs on them are fully capable of results of high value in conservation treatment, documentation and analysis.

CRESSIDA is a research and development team that is producing procedural manuals for IR reflectography imaging, computer-enhanced microscopy and digital confocal microscopy, graphics software for documentation, color matching and prediction of restoration treatments, examination of works of art in ultraviolet light, provenance studies, architectural erosion rate studies, comparison of commercial software offerings, and many other utilizations. In addition, the low end platforms of CRESSIDA is being studies as the launch platform for high end installation such as VASARI.

Membership in CRESSIDA is limited only to an institution's willingness to commit itself to an Apple Macintosh or Quada environment and participate in the CRESSIDA review meetings which take place every six months alternating between both coasts and Chicago.

PRESERVATION RESEARCH RELATED TO THE SWEDISH R&D PROJECT ON PAPER PRESERVATION

Ingmar Fröjd, *National Archives of Sweden*

The Swedish R&D Project on Paper Preservation (FoU-projektet för papperskonservering) is conducted by major public institutions concerned with the preservation of archival and library material. The main aims of the project are: to build up knowledge and competence in the field of preservation of paper, to evaluate available conservation methods, and to initiate and promote the production of long-lasting printing and writing paper grades.

The recently closed Nordic Fine Paper Project was initiated by, but not subordinated to the Swedish R&D Project on Paper Preservation. It was carried through by major cooperating Nordic research institutes and the R&D Project.

The project Effects of Air Pollutants on Cellulose Containing Materials is carried through by cooperating Dutch, French and Swedish participants within the STEP (Science and Technology for Environmental Protection) programme. The R&D Project on Paper Preservation is involved as a sponsor on behalf of Swedish interests.

The following presentation covers completed and current research within the framework of the Swedish R&D Project on Paper Preservation or research programmes linked to it through partner- or sponsorship, in order to give a complete overview of all related activities. Planned but not yet initiated tasks or tentative subprojects are not included.

1 The state of the art

1.1 Literature survey

By way of introduction, a literature survey was carried out to review the most important factors affecting the ageing and degradation of paper. The survey also included a short appraisal of test methods, effects of the papermaking process and printing, a comparison between natural and accelerated ageing, and a short introduction to some deacidification methods.

The survey resulted in a general assessment stressing the importance of initiating basic research to develop greater competence in the field of paper preservation, to improve storage conditions, to develop diagnostic methods for assessing the conditions and ageing stability of papers, to evaluate deacidification methods and, finally, to develop ageing stable wood-based papers. According to this assessment the project programme was set.

Status: Completed and reported by STFI under the leadership of Tom Lindström in *Ageing/Degradation of Paper —A literature survey.*

1.2 Damage survey

A damage survey has been completed at the National Archives, the Royal Library and the University Library of Gothenburg. The survey was carried out as an Uppsala Variant of the so called Stanford method, which had been established at a previous study at the University Library of Uppsala. This study had confirmed by chemical analysis that a simple test procedure based on folding by hand reflected the properties of the paper.

The results showed that the largest proportion of weak paper is in the material from 1860-1890, and that the average proportion in the investigated collections is about 20%. Brittle books are rare. The proportion of weak paper and the dating are considered to be representative on a national level.

Our experience of this method is that it is simple to use and gives reliable results when making a damage survey. The Uppsala Variant has later been used in a major survey at the Dutch National Archives and the Royal Library in the Hague, the Netherlands. The results were similar to the Swedish.

Status: Completed and reported by Jonas Palm and Per Cullhed (Uppsala University Library) in *Deteriorating Paper in Sweden — A Deterioration Survey of the Royal Library, Gothenburg University Library, Uppsala University Library and the National Archives.*

110

2 Methods for the characterization and evaluation of paper ageing

2.1 Natural ageing of paper

A collection of naturally aged papers, kept at the Swedish National Testing and Research Institute (Statens Provningsanstalt), has been investigated. The papers, manufactured from 1908 up to present time, had been tested within a couple of weeks after manufacture. These papers were reinvestigated with respect to strength properties, degree of sizing, and for some papers, copper number and acidity.

The retention of tensile strength is high, often more than 90% even after 80 years. The retention of elongation at break is around 70%. The fold numbers of papers manufactured up to roughly 1950 have changed considerably with retentions less than 20% for papers made from rag or from chemical pulp. The fold numbers were, however, approximately ten times higher for the rag papers. The changes are attributed to the acid sizing and, in some cases, to the low fibre quality. There is some correspondence between low copper number (low contents of easily oxidized components) and high retention of fold.

The properties evaluated in this subproject cannot account for all differences between papers on ageing. General descriptions in such terms as fibre composition and acidity are insufficient to predict permanence. A fair correlation between natural and accelerated ageing was observed, but the choice of ageing conditions is important. Accelerated ageing without moisture is apparently of limited value.

Status: Completed by Statens Provningsanstalt (Swedish National Testing and Research Institute) and reported by Marie Louise Samuelsson and Karin Sörner in *Naturligt åldrat papper - Svenska papper 1908-1988, with a summary: Natural Ageing of Paper — Swedish Papers 1908-1988.*

2.2 The physics and chemistry of paper ageing - A comparison between accelerated and natural ageing

Accelerated ageing at an increased temperature is generally used for the evaluation of ageing properties. There is however, no investigation that justifies the underlying assumption that accelerated ageing actually induces the same type of changes that a natural ageing process would do. Therefore, data from other subprojects within the Swedish R&D project on paper preservation together with additional chemical spectra (e.g. CP/MS NMR) will be subjected to multivariate data analysis in order to reveal the process of accelerated ageing in a few "latent" variables. Some selected series of old papers are evaluated in order to describe the natural ageing in a similar manner. The development of accelerated ageing will then be compared to that of natural ageing, and the relevance of accelerated ageing may be assessed.

Status: Carried out by STFI and still in progress. Coordinator Tommy Iversen.

2.3 Accelerated ageing of paper - A critical review of methods and evaluation

The effects of different ageing conditions on a wide range of paper samples have been investigated. The paper samples range from archival grades to unbleached kraft paper. The ageing conditions chosen are not only the widely used 80°C/65%RH and 90°C/50%RH, but also the more extreme conditions 95°C/65%RH. Several mechanical properties have been determined. Standard methods are used for tensile testing (incl. strength, stretch, elastic modulus, tensile energy absorption), tear testing and folding endurance. In addition to these methods, the Pulmac zero-span tensile strength and a so called fracture toughness test, developed at STFI, are included. The optical properties are also determined. The effects on paper properties of the different ageing conditions are compared, and the suitability of the various mechanical tests for monitoring these changes will be assessed.

Status: Carried out by STFI and the Swedish National Testing and Research Institute in cooperation. Almost completed. Coordinator Petter Kolseth.

2.4 Accelerated ageing of paper - The influence of papermaking variables

The ageing of paper is generally looked upon as a process in which the sheet becomes brittle. This embrittlement, or loss of toughness, is often monitored by measuring folding endurance or tearing resistance. The new method, the fracture toughness developed at STFI, measures a more well-defined fracture resistance of paper, which has been shown to work well in other situations where brittleness is a critical prop-

erty. We know of several papermaking variables that can make paper tougher (less brittle), but very little about how these variables affect the ageing process. In this subproject, the influence of several of these variables and of others, such as fibre furnish, beating, wet pressing, shrinkage during drying and calendering, on the accelerated ageing of paper are investigated.

Status: Carried out by STFI and still in progress. Coordinator Petter Kolseth.

2.5 Characterization of low molecular weight substances formed in aged paper and their correlation with strength loss

The natural ageing processes in paper lead to the formation of several low molecular weight compounds. However, knowledge of the composition of these compounds and their correlation to strength loss in aged paper is incomplete. In this subproject, aqueous extracts from aged paper samples are analysed in order to identify and quantify the formation of such compounds. Several analytical techniques including gas chromatography (GC), liquid chromatography (LC) and ion chromatography (IC) are used. The compounds identified so far include several low molecular acids, e.g. acetic acid, propionic acid and levulinic acid. The correlation between these and other cellulose and hemicellulose degradation products and paper strength parameters will be tested using multivariate data analyses. Further, the formation of low molecular weight compounds in natural and artificial ageing processes will be compared. This will provide insight into similarities and differences between the mechanisms leading to strength loss in these processes. The potential of using chemical analysis of minute paper samples to predict the condition of aged paper will be evaluated.

Status: Carried out by STFI and still in progress. Coordinator Marianne Björklund Jansson.

2.6 Correlation between ageing of paper and developed chemiluminiscence

Ageing of paper is mainly an oxidative process. In many oxidation reactions, reactive intermediates or the excited products formed may give rise to chemiluminiscence. The chemical reactions that occur during ageing sometimes leave traces of reactive structures like peroxides or excited carbonyls in the paper. In the methods that we use these unstable chemical groups are forced to relax. If the paper is treated with heat or with oxidation agents like hydrogen peroxide or oxygen in alkali, chemical reactions occur and if some of the energy is released as light it can be detected. Very weak light emission can easily be quantitatively determined using sensitive photomultipliers.

Samples of different origin and age have been examined. Chemiluminiscence was obtained by treating the paper sheets at an elevated temperature. The light is weak but measurable. The goal is to find a correlation with the degree of ageing. Since paper samples of a well-defined composition and history are not readily available, the absolute calibration on a realistic time scale of ageing is not a straightforward process.

Status: Carried out by STFI and still in progress. Coordinator Nils-Olof Nilvebrant.

3 Evaluation of conservation treatments

3.1 Effects of deacidification

The purpose of this subproject was to examine whether there were any differences in the effects of preventively or retrospectively deacidified papers exposed to simulated air pollutants (SO_2 and NO_2) and accelerated ageing. Effects of calcium hydroxide and magnesium methyl carbonate (MMC) were studied.

The results did not answer the question as to which treatment is generally to be considered the best. The additional alkali reserve created in the samples was about 1% unit carbonates, no matter which paper or treatment was used. There are however indications, that calcium hydroxide works better in preventive treatment whereas MMC works better as a retrospective treatment with respect to strength properties. There was a low correlation between pH, the rate of yellowing and the rate of degredation. Finally, the results indicate that certain air pollutants maybe react with the paper itself instead of with the buffer of magnesium carbonate.

Status: Completed by the Conservation Departement of Uppsala University Library with the assistance of the Departement of Inorganic Chemistry of Uppsala University, the Swedish National Testing and Research Institute, and STFI. Reported by Jonas Palm in *Preventiv och retroaktiv avsyrning av papper, with a summary: Preventive and Retrospective Deacidification of Paper.*

112

3.2 Evaluation of available mass treatment methods

A lot of data from different evaluations of mass treatment methods are now internationally available in the literature, and it appears not to be necessary to repeat all these tests. An independent evaluation based upon our own choice of test material and relevant methods is however, still required.

A selection of well characterized samples will therefore be treated (which naturally presupposes vendor cooperation) and evaluated with respect to immediately observed effects, and the properties determined by physical tests and chemical analysis. The long-term effects will be determined by physical characterization after accelerated ageing. The outcome of the evaluation of the effects of the treatments will create the necessary base for the next step in a total assessment, including cost accountings, logistics etc

Status: A recently initiated cooperative subproject. Coordinator Petter Kolseth.

4 Storage conditions and environmental effects on paper ageing

4.1 Storage conditions in archives and libraries

In order to obtain a picture of the general storage conditions in Swedish archives and libraries, the climate and common air pollutants were measured in some institutions. The institutions chosen were the same as in the damage survey (section 1.2) together with the Uppsala University Library.

With regard to one of the most interesting questions, it was established in the study that a considerable proportion of the incoming SO_2 and NO_2 in the supply air was deposited in the store rooms/stacks. No certain correlation between percentage SO_2 or NO_2 deposited and outdoor temperature, relative humidity or degree of air pollution was, however, established.

The results are compared with a study at Dutch archives and libraries which show some similarities with the Swedish study.

Status: Completed by the Swedish Environmental Research Institute (IVL) and on its way towards being published. Coordinator Ann-Beth Antonsson.

4.2 Effects on paper ageing of air pollution

4.2.1 Effects of nitrogen dioxide

Several studies have discovered the effects of sulphur dioxide on the ageing of paper and have clarified the mechanisms. The effects of nitrogen dioxide, which can attain considerable concentrations particularly in urban areas where most archives and libraries are located, is less clear.

The study shows, that the effects of the gas exposure and accelerated ageing depend on the composition of the paper. Acid-sized papers from chemical pulp lose their strength but the optical properties are affected to only a small extent. The mechanical properties of acid-sized wood-containing paper were not affected either, but the optical properties were strongly affected leading to discoloration. Neither the mechanical nor the optical properties of neutral-sized paper from chemical pulp or rag were affected by the exposure and ageing, apparently because the calcium carbonate filler neutralized acid substances. The study indicates the importance of further research on the effects of interaction between nitrogen dioxide and other pollutants, e.g. sulphur dioxide.

Status: Carried out by STFI and reported by Tommy Iversen and Jiri Kolar in *Kvävedioxids effekter på papper, with a summary: Effects of Nitrogen Dioxide on Paper.*

4.2.2 Effects of common air pollutants in combination

Since most archives and libraries are located in cities, the air supply to the store rooms may contain rather high concentrations of air pollutants. The objectives of this subproject are to evaluate paper ageing due to combined exposure to the common air pollutants SO_2/NO_2, compared to the negative effects of each of the components at sub-ppm levels. The effect of ozone will also be investigated.

By measuring the deposition of pollutants to the surface of a material, it is possible to obtain information regarding the reactivity of the material. The deposition of SO_2 and NO_2 at sub-ppm concentra-

tions is studied on different types of paper. The experimental set up used in this study has been developed in order to perform the ageing under carefully controlled conditions.

The results show that paper containing groundwood exhibits the largest SO_2 deposition at high and moderately values of relative humidity, while the uptake on paper based on chemical pulp (sulphate) shows a smaller increase under similar conditions. The results also indicate that the neutral sized papers have a larger uptake of SO_2 than the rosin sized papers. The results are obtained for both ground wood and chemical pulp.

The presence of NO_2 increases the uptake of SO_2 for all papers. The most dramatic effects were observed at high humidity and for papers containing $CaCO_3$. Earlier studies have shown that humid SO_2 atmospheres containing NO_2 drastically increase the corrosion of calcerous stones. The same effects are observed on $CaCO_3$ containing papers.

Status: Carried out by CTH/GU and STFI in cooperation and on its way towards being published. Coordinator *Anna Johansson*.

5 Effects of climate, air pollution and mass treatment

5.1 STEP project effects of air pollutants on cellulose containing materials

This project is carried out by CRCDG, CTH/GU, STFI and TNO Centre for Paper and Board Research in cooperation. The objectives are described as follows (from the General Project Information).

To determine the effects of climate and air pollutants, especially synergistic effects, on the stability of cellulose materials with regard to paper-based material in archives, libraries and museums. Most of the deterioration effects are attributed to the acidification of the materials; therefore de-acidification is recommended. However, the effects of the de-acidification process and especially the effects of air pollutants on de-acidified materials are unknown.

The project seeks to answer the following questions:

- What are the synergistic effects of various air pollutants on the stability of the selected materials?
- Will continuation of air pollutants cause an accelerated deterioration of old and naturally aged materials?
- Will continuation of air pollutants cause an accelerated deterioration of the de-acidified materials?
- What is the threshold level or response surface of the air pollutants or at what rate of deposition does accelerated deterioration occur?
- How are old papers (books) resistant to air pollutants?
- What are the internal effects of different paper grades in combination with air pollutants on the future stability?
- What are the effects of the selected commercial mass de-acidification processes?

After evaluating the answers to these questions, recommendations may be given on:

- the future stability
- the best storage conditions and
- the usefulness of de-acidification.

Status: In progress and scheduled for completion in 1994. So far one workshop report has been published, edited by John Havermans and Anita Bouman, *The Effects of Air Pollutants on the Accelerated Ageing of Cellulose Containing Materials*. Coordinator John Havermans for further information.

6 Research in order to initiate and promote permanent products

6.1 Effects on permanence of modern pulp bleaching methods on paper of chemical pulp

New bleaching processes are now being rapidly developed. We have however, no knowledge about the way the new methods affect the ageing. In this subproject, new bleaching sequences already in practice and sequences believed to be adopted for chemical pulp in the near future are being studied.

Status: Carried out by STFI and still in progress. Coordinator Tommy Iversen.

6.2 Nordic Fine Paper Project

The Nordic Fine Paper Project was carried out by GFL, KCL, PFI, STFI, STORA Papyrus Forenede Papirfabrikker and the Swedish R&D Project on Paper Preservation in cooperation. The purpose of the project was to create a scientific basis for a broader supply of permanent products. (The project was originally intended to deal with research on fine paper but

114

was later extended to deal with issues beyond the definition of fine paper.)

6.2.1 Effects of resin

Laboratory handsheets of four commercially available pulp grades; bleached and unbleached groundwood pulp (SGW) and chemithermomechanical pulp (CTMP) from the same manufacturer have been investigated. The properties of sheets of the original pulps have been compared with sheets from the same pulps after resin and other wood components have been removed by extraction. Water absorption tests show that the extraction has had an effect primarily on the bleached pulps. In the unbleached pulps, the resin is probably still present.

The mechanical properties of the sheets deteriorate on ageing. Tensile tests are not affected by extraction. The tensile energy absorption index and strain to failure are affected positively by extraction. The results indicate that the breaking of bonds between the fibres has predominated, probably through the migration of resin or other extractive substances which are present especially in mechanical pulps. The brightness was not changed by the extraction.

Status: Completed by STFI and reported by Tommy Iversen and Petter Kolseth in *Hartsets inverkan på åldring av papper av högutbytesmassa*.

6.2.2 Effects on ageing of lignin-preserving bleaching

Laboratory sheets of unbleached and peroxide-bleached chemithermomechanical pulp and semi-chemical pulp were compared with reference sheets of bleached sulphate and cotton linters, after accelerated ageing extended to 150 days.

Much of the study concerns the most critical properties from a commercial viewpoint, i.e. the brightness and yellowing. After 150 days´ ageing, all sheets were strongly affected. The sheets of high yield pulps, bleached and unbleached, have for instance an ISO-brightness below 30%. Both the brightness and yellowness values and also the tear index exhibited a more or less parallel development. The strength reduction patterns for the bleached and unbleached high yield pulps are parallel.

The conclusion is that peroxide bleaching in itself has no negative effects on the ageing stability. Brightness and strength do not develop in the same way because of competing reactions which affect the properties at different rates. It is therefore doubtful whether products with completely different compositions should be evaluated by the same ageing method. The practical consequences of this must be observed if accelerated ageing is applied in standards.

Status: Completed by PFI and reported by François A. Abadie-Maumert and Einar Bøhmer in *Blekingens innvirkning på treholdig papirs aldringsstabilitet*.

6.2.3 Ageing stability of wood-containing papers

Paper samples containing sulphite pulp and high-yield pulp in different proportions were investigated in order to map out the influence on the ageing stability of three important variables; pH, alkali reserve and the content of mechanical pulp.

An alkali reserve in the paper seems to have had a very large positive effect and seems partly to be able to cancel effects of acid sizing. The best result is attained with both neutral sizing and a high alkali reserve. Neutral-sized paper with no alkali reserve is more stable than acidic-sized paper with an alkali reserve with regard to optical properties, whereas the opposite relationship is true with regard to tear index.

It does not seem to be important for the ageing stability if the content of mechanical pulp is increased from e.g. about 40% to about 70%.

The relationship between accelerated ageing and natural ageing is discussed. It is evident that the ageing test time is of decisive importance in any comparative evaluation of papers with different compositions. Accelerated ageing (80°C/65%RH) for 7 days is obviously too short a time for any long-term forecast concerning the paper. The results show that the samples with a high pH-value and high alkali reserve become better the longer the ageing time.

Status: Completed by PFI and reported by François A. Abadie-Maumert and Einar Bøhmer in *Aldringsstabilitet hos nøytralt treholdig papir*.

6.2.4 Permanence of coated papers and coating layers

Knowledge about the permanence of coated papers is very rare and scarcely documented in the

literature. The permanence of commercial coated printing and writing papers, as well as laboratory-scale coated papers was investigated. The permanence was evaluated in terms of strength properties, predominantly tear strength, and brightness at accelerated ageing.

The results showed that the permanence of coated papers is as good as or even superior to that of uncoated papers wtih the same type of fibre composition. The coating may thus act as a protective layer on the fibrous matrix. No indication of decreasing surface strength or coating split off upon ageing was observed.

As for uncoated papers, neutral pH and consequently the use of calcium carbonate are essential for the permanence of coated papers. Wood-containing papers are in this respect no exception.

The decrease in brightness is remarkable after accelerated ageing of coated papers (in darkness). This applies especially to acid wood-containing papers. However, here again neutral pH and the use of calcium carbonate are advantageous because they improve the brightness stability of the base paper, as well as of some unstable coating formulations.

The subproject includes a preliminary study with chemiluminescence technology.

<u>Status</u>: Completed by KCL and STFI in cooperation and reported by Björn Krogerus, Jouko Laamanen and Mikael Rigdahl in *Bestrukna pappers åldringsbeständighet.*

6.2.5 <u>Effects on ageing stability of printing</u>

The effects of lithographic offset printing on ten common book and magazine papers from different manufacturers were investigated. All the test papers were neutral sized and clearly alkaline except one, and two contained a proportion of mechanical pulp. To obtain the maximum effect, the samples were exposed to extreme printing; one half of the samples was printed in full-tone on both sides and the other half with an acidic fountain solution in all four printing stations.

For most papers, neither the printing ink nor the fountain solution had any noticeable effect on the strength properties, and the optical properties were relatively stable after the fountain solution treatment. The exceptions were two uncoated samples with relatively low pH´s and no or small alkali reserve, and an uncoated neutral-sized woodfree paper with an alkali reserve.

This investigation confirms that accelerated ageing (80°C/65%RH) must take place for a long period of time to give reliable tendencies in relation to the original values. High initial strength or brightness is no guarantee in a long-term perspective.

In general, the investigation confirms that neutral/alkaline sizing and an alkali reserve contribute considerably to improving the ageing resistance of the product, even after offset printing with acidic fountain solution.

<u>Status</u>: Completed by GFL and PFI in cooperation and reported by François A. Abadie-Maumert and Anders Bovin in *Åldringsstabilitet hos tryckt papper.*

6.2.6 <u>Permanence of books</u>

The subproject deals with the ageing of books from a strength point of view. Instead of ageing complete books, the components of the book were aged separately or in combinations of two, to find out what is weakened during ageing. Two dispersion adhesives (with internal and external softeners), one hot-melt adhesive, adhesive-coated papers, two binding threads (nylon and polyester) and folded sheets were evaluated after accelerated ageing

The dispersion adhesive with an internal softener was hardly affected at all, whereas the adhesive containing an external softener was affected already after one week´s ageing, probably because the softener migrated so that the adhesive became brittle. It was not possible, however, to study the ageing of the hot-melt adhesive since the ageing temperature exceeded the adhesive´s melting point. No deterioration was observed in the tear strength of the paper as a result of any interaction between adhesive and paper.

The threads was not affected negatively during ageing, and adhesive coating had no negative effect either. The effects on the folded sheets showed no clear tendency.

<u>Status</u>: Completed by GFL and reported by Mårten Gomer and Göran Lindholm in *Åldringsbeständighet hos böcker, with a summary in English.*

7 <u>Presentation of results</u>

Completed subprojects within the research programme of the Swedish R&D Project on Paper Preservation (sections 1-4 and 6.1) are or will be published in the series of reports of FoU-projektet för papperskonservering (ISSN 0284-5636), as well as a summary of the Nordic Fine Paper Project.

Subprojects carried out within the Nordic Fine Paper Project (section 6.2) are reported by the responsible institutes respectively. The same applies to the EC STEP project Effects of Air Pollutants on Cellulose Containing Materials (section 5.1).

ABBREVIATIONS

CRCDG	Centre de Recherches sur la Conservation des Documents Graphiques
CTH/GU	Chalmers University of Technology and University of Gothenburg
GFL	Swedish Graphic Arts Research Laboratory
KCL	Finnish Pulp and Paper Research Institute
PFI	Norwegian Pulp and Paper Research Institute
STFI	Swedish Pulp and Paper Research Institute
TNO	Netherlands Organization for Applied Scientific Research

REFERENCES

Abadie-Maumert, F. A. [ed. Bøhmer, E.], *Aldringsstabilitet hos nøytralt treholdig papir*. SCAN Forsk report 577, PFI report 5/1991.

Abadie-Maumert, F. A. [ed. Bøhmer, E.], *Blekingens innvirkning på treholdig papirs aldringsstabilitet*. SCAN Forsk report 578, PFI report 6/1991.

Abadie-Maumert, F. A., Bovin, A., *Åldringsstabilitet hos tryckt papper*. SCAN Forsk report 590, GFL report 73, 1991.

Fellers, C. et al. [ed. Lindström, T.], *Ageing/Degradation of Paper - A literature survey*. Stockholm 1989. FoU-projektet för papperskonservering, report No. 1E (in Swedish as report No. 1).

Gomer, M., Lindholm, G., *Åldringsbeständighet hos böcker*. SCAN Forsk report 576, GFL report 72, 1991.

Havermans, J., Bouman, A., *The Effects of Air Pollutants on the Accelerated Ageing of Cellulose Containing Materials*. 1st Workshop, TNO 1992.

Iversen, T., Kolar, J., *Kvävedioxids effekter på papper*. Stockholm 1991. FoU-projektet för papperskonservering, report No. 5.

Iversen, T., Kolseth, P., *Hartsets inverkan på åldring av papper av högutbytesmassa*. SCAN Forsk report 592, STFI 1991.

Krogerus, B., Laamanen, J., Rigdahl, M., *Bestrukna pappers åldringsbeständighet*. SCAN Forsk report 571, KCL 1991.

Palm, J., *Preventiv och retroaktiv avsyrning av papper*. Stockholm 1991. FoU-projektet för papperskonservering, report No. 6.

Palm, J., Cullhed, P., *Deteriorating Paper in Sweden - A Deterioration Survey of the Royal Library, Gothenburg University Library, Uppsala University Library and the National Archives, Stockholm 1988*. FoU-projektet for papperskonservering, report No. 3 (in a Swedish version as report No. 2).

Samuelsson, M. L., Sörner, K., *Naturligt åldrat papper — Svenska papper 1908-1988, Stockholm 1990*. FoU-projektet för papperskonservering, report No. 4.

Ingmar Fröjd is coordinator of the Swedish Research and Development Project on Paper Preservation and the coordinator of the Nordic Fine Paper Project. He is also involved in the STEP project on the Effects of Air Pollutants, as a sponsor.

LIBRARY OF CONGRESS
MASS PRESERVATION RESEARCH AND DEVELOPMENT ACTIVITIES

DONALD SEBERA, *LIBRARY OF CONGRESS*

INTRODUCTION

Many of the research activities currently being conducted by the Research and Testing Office of the Preservation Directorate have already been described. The Directorate also has programs of research and development focussed on various aspects of mass preservation. Two major programs - mass deacidification and preservation/access systems - will be described here.

MASS DEACIDIFICATION PROGRAM

To place the current mass deacidification program in contex,t some previous actions and events are reviewed. In 1989, the Library's program to complete the engineering development of the DEZ process was successfully concluded. Process parameters and a plant design for a one million book-per-year facility were developed. However, some other issues such as residual odor and iridescence on book covers remained.

It was expected that Akzo Chemicals, which had been awarded a license to the DEZ process, would complete these aspects of process development and refinement. Other mass deacidification process vendors, however, asserted they were already capable of satisfactorily deacidifying the Library's book collection at the one million book-per-year rate. Therefore, in response to a request for proposals (RFP 90-21), three firms, including Akzo Chemicals, initially bid.

Technical evaluation of the final two bids was made by an independent panel which concluded that none of these firms/processes fully met all of the Library's requirements. The panel also concluded that the DEZ process had the highest potential for improvement to the acceptable level.

The Library was deeply disappointed by these results and canceled the procurement. Recognizing the important role of deacidification in any mass preservation strategy, it decided, with Congressional approval, to complete the development of the more promising DEZ process. It also recognized that other deacidification technologies may be developed or improved which also can fully meet the Library's requirements stated in RFP 90-21. Such technologies should be assisted and evaluated by the Library.

Before proceeding with a second procurement effort, the Library needs to be certain that some processes can fully meet its requirements. Continuing evaluation of all deacidification processes is therefore called for.

A mass deacidification program was formulated addressing these issues—completion of DEZ development by the Library and assistance to other firms utilizing different processes to help them meet the same requirements. At the point where at least one of the processes can fully meet the RFP 90-21 requirements, the Library will proceed with open competition for mass deacidification services.

An Action Plan implementing these ideas has now been approved by Congress, providing funding for the first phases. This report describes current development activities in pursuance of the Action Plan.

DEZ DEVELOPMENT EFFORT

The DEZ development effort is a one year R&D program under the direction of the Library. It is anticipated that the adverse effects observed in the canceled procurement can be resolved. The chemical and physical factors influencing odor and other adverse effects can be determined and can hopefully be brought to acceptable levels through optimization of plant equipment and through laboratory scale experimentation. The future viability of the DEZ deacidification process hinges on the outcome of this development program. Following is a brief summary of actions already undertaken and planned.

A one-year contract with Akzo Chemicals is being negotiated for 12 test runs in the Deer Park,

Texas Pilot Plant. Additional laboratory scale testing to identify odor causes and prevention will be obtained through university contracts. Test run conditions, including modifications to the plant and process procedures, are to be defined by the Library.

The general program for the one-year development as well as specific test run materials and conditions will be determined by a Technical Management Team working with Gerald Garvey, the Preservation Projects Officer. This team is composed of Library Preservation and Conservation staff and several consultants, including two professors of chemistry, three consulting chemical engineers, and three individuals from Akzo Chemicals.

The one-year program will formally begin with the award of contracts in the next few weeks. It is anticipated that in the next 6-7 months extensive tests will be conducted to optimize plant conditions and identify the factors which produce adverse effects. Subsequent tests will address any remaining adverse effects and incorporate the whole range of Library book materials. The remaining test runs are planned as a demonstration of the ability of the DEZ process to fully meet all the technical requirements of RFP 90-21.

SMALL SCALE DEZ DEMONSTRATION

After the first-year development effort demonstrates fully satisfactory results using test materials, a second one year program is planned for treating approximately 50,000 books from the Library's collections. The observations made and experience gained in this one-year demonstration will be utilized to determine if the DEZ process can routinely deacidify books to the standards established by RFP 90-21.

EVALUATION OF OTHER DEACIDIFICATION PROCESSES

In addition to developing the DEZ process, the Library is prepared to assist other technologies through testing and evaluations. It is clearly in the interest of the Library and the public to encourage and appropriately foster development of all deacidification processes. Ultimately, this approach will secure the most effective and least costly method(s). Though in the technical government procurement sense, this cooperation does not constitute "prequalification," it does permit a reasonable determination that a process fully meets the Library deacidification requirements stated in RFP 90-21. The evaluation activity is a three-stage process.

1. A processor (at his initiative) who wishes to be evaluated submits currently available details about the chemistry, toxicity, environmental impact, efficacy and adverse effects of his process and at least three treated books to the Library. The submission will be evaluated and given preliminary testing. The results, evaluations and opinions concerning the process and its potential for development into a mass deacidification process will be reported to and discussed with the processor.

2. After the processor has, in his judgement, corrected deficiencies identified in the first submission, a second more detailed submission is made. The Library will provide 30 characterized books which are to be deacidified and returned to the Library for testing and evaluation. Upon completion of this second testing and evaluation the results and opinions will be reported to and discussed with the processor.

3. When, in his judgement, the processor is ready for full preliminary testing and evaluation, another submission containing details of chemistry, toxicity, environmental impact, efficacy and adverse effects will be made along with engineering and other information appropriate to operating at the 300,000 + book-per - year level. On the basis of the previous tests and the new submission, the Library will decide whether to provide the processor with a demonstration set of 500 books for his processing and evaluation by the Library. The results of testing and subsequent evaluation and the opinions of the Library will be reported to and discussed with the vendor.

The Library will share the results and subsequent evaluations with the preservation community at all three stages.

MASS DEACIDIFICATION PROCUREMENT

Through this combination of the DEZ development program and assistance to other deacidification processes, the Library is supporting the technical development of mass deacidification. The Library will then initiate competition for deacidification services

to preserve its book collections, with the intention of selecting one or more firms that are capable of fully meeting its requirements—essentially those in RFP 90-21. The Library expects to initiate mass deacidification of its book collection at the 300,000 book/year level in 1995.

Following this article are the text of the Librarian's letter trasmitting the Action Plan to Congress and a summary description of the plan.

DEVELOPMENT OF PRESERVATION/ ACCESS SYSTEM

Though mass deacidification has received a high priority in planning for increasing the permanence of its book collection, the Library has not ignored understanding and utilizing other methods for increasing the permanence of collections through strengthening, environmental and pollution control, boxing, etc. In recent years, increasing attention has been given to integrating rapid access of collections with collections storage under enhanced preservation conditions. The concept of "preservation on demand," i.e., undertaking specific preservation actions for an item only when there is a call for that item, has long been recognized as having the potential for both cost savings and more rapid access. With the Library's collection rapidly approaching storage capacity, strong impetus must be given to the development of a comprehensive strategy for combining preservation storage with rapid access.

It is necessary to consider how collection condition and longevity are affected by patterns of use, rate of use, environmental conditions, deacidification, paper strengthening, and housing. Consideration must also be given to the characteristics of any access system. In addition, any prospective strategy for a preservation/access system must allow for growth over many decades in the size of the collections and in changing access and format transfer systems.

Because of the multiplicity, complexity and interdependence of the components, a flexible management structure for research and development will be employed.

In all these efforts, the Library seeks to cooperate and collaborate with other institutions. There is already in place a formal agreement with the Swiss National Library and Swiss Federal Archives to share information about mass deacidification and other preservation topics. Thus, the Library will continue to seek advice and to share with others in the preservation community its planning and the results of its research.

Since 1981, Donald Sebera has been a Chemist in the Preservation Research and Testing Office, Preservation Directorate, Library of Congress, with major responsibilities in the area of paper preservation, especially mass deacidification technology. Previous preservation experience includes teaching in conservation training programs at Cooperstown and Winterthur. He has taught graduate and undergraduate courses in chemistry. He held research positions at the Canadian Conservation Institute, and in the petroleum industry. He was Officer, Chemical Corps U.S.A. He is past president (1976-1978) of the American Institute for Conservation of Historic and Artistic Works. He holds a Ph.B, SM and Ph.D from the University of Chicago.

May 27, 1992

Dear Mr. Chairman:'

In response to concerns expressed in your letter of February 25, regarding the Library's pursuit of a viable mass deacidification technology, our General Counsel and other officers of the Library met twice with the General Counsel of the General Accounting Office. His perceptive observations and recommendations were most constructive. Library personnel also met with Appropriations Committee staff members and have considered their helpful comments and advice as well in developing the Library's revised Deacidification Action Plan. I am forwarding that plan for your review and approval.

Recent research and consultations have reaffirmed our conclusion that it is in the best interest of the Government and of the library community for us to make every effort to perfect the development of the diethyl zinc (DEZ) process, which our expert advisory panel found to be the technology exhibiting the most promise of meeting the Library's technical requirements. The Swiss Government has just completed evaluating several deacidification processes and has also concluded that DEZ has a higher chance of improvement. The Swiss Federal Archives and the Swiss National Library will concentrate their efforts primarily in further testing the DEZ process. In addition, all American research libraries, at least 16 to date, that have evaluated deacidification processes have reached similar conclusions about the DEZ process.

We are presenting a revised Action Plan designed to perfect the DEZ process and to assist as well in the development of other deacidification processes. The Library's Action Plan consists of two competitive phases which would run concurrently for two years, culminating in a third stage that would result in competitive contracting for production-level deacidification services.

Phase A of our Action Plan would include a one-year effort,under Library of Congress leadership, aimed at eliminating theremaining problems identified during our procurement effort last year. The program will require contracting for 12 tests at a DEZ deacidification facility. A notice of our intention to award a sole source contract to Akzo Chemicals for these tests will appear in the the Commerce Business Daily. If this one-year development effort is successful, it will be followed by a one-year competitively awarded contract to demonstrate and test successful ongoing small scale operation of the DEZ deacidification process. Approximately 50,000 books from the Library's collections will be deacidified using the DEZtechnology.

Phase B, running concurrently with Phase A, consists of a two-year program to encourage and facilitate the development of other deacidification processes by providing testing and evaluation opportunities as

well as technical information to interested firms offering deacidification services. The goal is to provide other firms with a meaningful opportunity to demonstrate that they can meet or exceed the Library's deacidification requirements (complete deacidification, adequate alkaline reserve, 300% increase in paper permanence) without damage to collections.

Phase C is a competitively awarded contract for deacidification services for five years at an initial rate of 300,000 books a year. This Phase would begin only after the Library determines that one or more processes can meet all of its deacidification requirements. The long-term goal continues to be treatment of one million books a year.

I believe that the enclosed, revised Action Plan fully meets the Library's interests and that it addresses the concerns you have expressed. Accordingly, I am asking the Committee's approval to release $1,325,000 in deacidification funds withheld from obligation in order to proceed with the mass deacidification program for the next two years.

Thank you for your continued interest in and support of the Library's preservation activities. We will keep you informed as our program for deacidification services progresses.

Sincerely,

James H. Billington
The Librarian of Congress

Enclosures

The Honorable
Vic Fazio
Chairman, Subcommittee on
Legislative Branch Appropriations
Committee on Appropriations
U.S. House of Representatives
Washington, D.C. 20515-6025

LIBRARY OF CONGRESS

ACTION PLAN FOR THE MASS DEACIDIFICATION PROGRAM

May 21, 1992

ACTION PLAN

The Proposed Mass Deacidification Action Plan consists of a three-phase program. Phases A and B are to run concurrently; they are designed to attempt to facilitate perfected development of the most promising deacidification technology (DEZ), and to encourage further development of other deacidification technologies. Phase C will be a competitively awarded procurement for any mass deacidification services.

PHASE A. EFFORT TO PERFECT THE DEVELOPMENT OF THE DEZ DEACIDIFICATION TECHNOLOGY

DEZ DEVELOPMENT EFFORT 1992/93

Duration: 1 year Estimated Cost $ 375,000

Objective: Resolve odor, discoloration, and other problems.

One-year effort to complete the development of the DEZ process. A team of technical specialists, under the leadership of the Library of Congress, will conduct a series of tests of the DEZ process to correct odor and other problems. If successful, development will be followed by a one-year competitively awarded contract to test and demonstrate ongoing small scale operation of the DEZ process using typical Library material.

COMPETITIVE CONTRACT FOR DEMONSTRATING AND TESTING SMALL SCALE DEZ OPERATIONS 1993/94

Duration: 1 year Estimated Cost $ 750,000

Objective: Successful deacidification of typical Library material

with the DEZ process operating at an ongoing, small test scale.

Approximately 50,000 books from the Library's collection will be deacidified using the DEZ process.

PHASE B. EVALUATE OTHER DEACIDIFICATION PROCESSES 1992/94

Duration: Two years (Concurrent with phase A) Estimated cost: $ 200,000

Objective: Foster competition for deacidification services.

Library of Congress to assertively evaluate and test other deacidification processes. The Library will provide evaluation guidelines to firms interested in having their deacidification processes evaluated by issuing a Request For Information (RFI) in the Commerce Business Daily.

PHASE C. MASS DEACIDIFICATION PROCUREMENT 1994/99

Duration: 5 years Estimated cost: $4,500,000 per year

Objective: Implement the mass deacidification of the Library's collections.

When the Library determines that a process or processes can meet all deacidification requirements, competitively contract for mass deacidification services initially at 300,000 books a year for five years.

The long term goal for the Mass Deacidification Program continues to be treatment of one million books a year.

PRESERVATION RESEARCH AT THE LIBRARY OF CONGRESS: RECENT PROGRESS AND FUTURE TRENDS

CHANDRU J. SHAHANI, *LIBRARY OF CONGRESS*

Laboratory research in support of library and archive preservation has been a long and productive tradition at the Library of Congress. Several new research projects in selected areas of investigation have been undertaken over the past few years. The nature of these research projects, their progress and present status are described below.

1. Research on Deacidification of Paper

1.1 Determination of optimal alkaline reserve:

In spite of the extensive literature on deacidification of paper and the recent proliferation of mass deacidification processes, no experimental data have been reported on how much alkaline reserve is needed to obtain the highest gain in stability. In this work, the influence of basic magnesium carbonate on the permanence of paper was studied over a wide concentration range in an effort to determine the optimal alkaline reserve content that should be imbibed into paper in a deacidification process. Test papers were deacidified by immersion in a freon/methanol solution of methyl magnesium carbonate. The alkaline reserve content of the test samples was varied by manipulating the concentration of the treatment solution. The rates of degradation of the test samples have been compared after subjecting them to accelerated aging. The benefit of increasing alkaline reserve reached a limiting point of maximum stability within about 2 percent alkaline reserve for weaker papers. However, stronger papers continued to gain in stability with increasing alkaline reserve content, even up to 5 percent magnesium carbonate, which was the highest alkaline reserve content studied in this work.

Status: Presented at American Chemical Society's Symposium on "Historic Textile and Paper Materials: Conservation and Characterization - II" in 1988, by Chandru J. Shahani, Norris Lindsey and Frank H. Hengemihle.

1.2 Comparison of aqueous and non-aqueous deacidification processes:

In this work, the relative stabilities of paper samples deacidified in an aqueous magnesium bicarbonate bath, and those treated in a freon/methanol bath of methyl magnesium carbonate have been compared after aging them at 90°C and 50% RH. The samples deacidified by the aqueous treatment age much more slowly, even when impregnated with only a small fraction of the alkaline reserve contained in the samples deacidified from the nonaqueous system. In all probability, swelling of the cellulose matrix in water must facilitate the penetration of the deacidification agent.

Status: To be published in 1993 by Frank H. Hengemihle and Chandru J. Shahani.

1.3 Comparison of calcium, magnesium and zinc-based aqueous deacidification systems:

1.3.1 Effects on colors and solubility of ink and pigment media:

Paper conservators working on individual objects, when faced with a decision whether to deacidify or not, all too frequently choose not to deacidify. Their reluctance to deacidify is due mainly to the fact that the colors and tints of many pigments and inks are sensitive to changes in pH value. Deacidification treatments function essentially by raising the pH value of paper. However, different deacidification systems raise the pH value of paper to a different extent. Solubilities of ink and pigment media are also expected to be influenced by the deacidification agent. In this project, the effect of calcium, magnesium and zinc-based deacidification treatments on selected pigments and inks will be compared.

Status: This project has just been initiated in

collaboration with the Conservation Office and is at an early stage of investigation.

1.3.2 Resistance to biological attack:

In general, acidic materials are more resistant to fungal growth than alkaline materials. In deacidifying our collections, do we increase their vulnerability to micro-organisms? Also, do the calcium, magnesium and zinc ions influence the growth of mold and mildew? Calcium salts generally provide a hospitable environment for biological growth, and some zinc salts have an opposite effect. A comparison of the three major deacidification systems would be most useful.

Status: To be initiated in 1993.

2. Other Chemical Treatments

2.1 Post-fumigation release of ethylene oxide:

The carcinogenic nature of this effective but hazardous fumigant is now well established. Federal regulatory bodies have responded by lowering the maximum permissible exposure to a time-weighted average of 1 part per million of ethylene oxide. The exposure of operational personnel during the fumigation process can be controlled by monitoring ethylene oxide concentrations inside and outside the fumigation chamber. A more important concern is the slow release of absorbed ethylene oxide from treated materials over an extended post-fumigation period. Which materials tend to hold on to ethylene oxide strongly enough to warrant greater caution in their treatment? In an attempt to answer this and other related questions, several library materials were treated with ethylene oxide, and their off-gassing rates were measured over an extended post-fumigation period. Photographic materials, wood and newsprint were seen to hold on to ethylene oxide most tenaciously. Off-gassing rates were considerably smaller, although still appreciable, for a small stack of randomly selected books and for modern bleached kraft book paper with alum-rosin size. Leather scraps and audio records made of PVC showed only a minimal affinity for ethylene oxide.

Status: This work was presented at the International Biodeterioration Society's Annual Meeting in 1986 by F. H. Hengemihle, N. Weberg and C. J. Shahani.

2.2 Investigation of paper strengthening processes:

The deacidification process can retard the degradation of paper, but it cannot restore the strength of aged paper. While some mass deacidification processes can probably incorporate an additional chemical to strengthen weak paper, none of them has yet demonstrated such a capability to our satisfaction. However, at least a few processes that can indeed strengthen brittle paper have become a reality. The British Library has developed a graft copolymerization process. This is a liquid phase process. Union Carbide's Nova Tran unit has utilized a vapor phase Parylene coating process. We have completed a study of the Parylene process that suggests it has potential for strengthening of paper-based objects. We have confirmed the fact that Parylene is a relatively stable material, and does not adversely influence the stability of paper. Potential for general application of a Parylene paper strengthening process on a mass scale appears limited since experimental parameters for deposition of Parylene and the corresponding benefit can vary widely with different types of paper. Its major strength lies in treatment of extremely delicate single items that are so badly deteriorated that they are hard to handle or treat by other conservation treatments. We intend to continue our investigation of strengthening processes as their development progresses.

Status: Early data of an investigation of the Parylene process was presented at the AIC Annual Conference in 1989 by Frank H. Hengemihle and Chandru J. Shahani. Further work was carried out over 1991 and 1992 by Sang B. Lee, Norman Weberg and Chandru Shahani. Publication of a short note in 1993 is planned.

3. Environmental Effects

3.1 Effect of contained or micro-environments on the stability of paper:

We have observed that under accelerated aging conditions (90°C and 50% RH) acidic paper ages faster when it is isolated from the environment, as for example, when paper is sealed within a polyester envelope, or inside a glass tube. Even acid paper within a book has been seen to age faster than a single sheet of the same paper that is free to interact with the atmosphere. However, alkaline paper does not age any faster inside an air-tight enclosure. The adverse

126

effect of containment on acid paper can be nullified either by deacidifying it, or by inserting a sheet of alkaline paper in contact with it. We have demonstrated that the enhanced aging of acidic paper inside an enclosure is an autocatalytic process that becomes increasingly faster as degradation products accumulate. This finding questions the validity of conventional accelerated aging methodology in which single sheets of paper are aged in a flow of air that carries away acidic degradation products that otherwise accumulate within a paper mass.

The objective of the current phase of this work is to investigate if the reaction mechanism by which paper ages within an impermeable envelope is similar to the one by which it ages under ambient conditions. The degradation products produced as a result of accelerated aging in loose, or open paper samples, and those sealed within impermeable envelopes or glass tubes, will be identified and compared with each other, as well as with degradation products present in naturally aged paper.

In a related project, the effect of storage within acid and alkaline box enclosures and folders is also being investigated.

Status: This work continues to progress. Early findings of this study were presented at AIC Annual Conference in May 1988 by Norris Lindsey, Frank H. Hengemihle and Chandru Shahani. More recent findings were presented at a Library Preservation Planning Conference at the National Library of India in December 1990. The completed study by Sang B. Lee, Frank H. Hengemihle and Chandru Shahani will be published in 1994.

3.2 Effect of cycling relative humidity conditions on the aging of paper:

The effect of fluctuations in relative humidity on the degradation of paper-based materials under accelerated aging conditions was studied to better comprehend environmental needs for long-term storage of paper-based archival materials. The rate of accelerated aging of paper samples subjected to a relative humidity cycling between 40 and 60 per cent at 90°C, was compared with corresponding data for samples aged under constant relative humidity conditions of 40, 50 and 60 per cent at the sample temperature. Test samples were aged as single sheets, as well as within stacks which simulated books. Invariably, test papers in stacks aged faster than those hung loosely on racks. Also, the adverse impact of cycling relative humidity conditions on the stability of paper was unmistakable. However, the test papers in stacks exhibited a greater resistance to changing relative humidity conditions.

Status: The first phase of this work by F. H. Hengemihle, N. Weberg and C. J. Shahani was published in "Historic Textile and Paper Materials - II," American Chemical Society, Washington, D.C., 1988. The second phase, which will investigate the effects of wider and faster cycles in relative humidity and temperature will be initiated in late 1993.

3.3 Comparison of rate of change in environmental conditions inside and outside of books and manuscript boxes:

Many factors are generally considered in planning for environmental conditions and controls for a new library or archive storage facility. To the best of our knowledge, no consideration has yet been given to the time lag between the actual change in temperature and humidity and the response within a book or a manuscript box. If this response time is long enough, small fluctuations in environmental conditions may not be as significant as they are generally perceived to be. Considerable savings can result from requiring less stringent environmental controls. In this work, temperature and humidity sensors placed in cavities within books were monitored as environmental temperature and relative humidity conditions cycled between programmed extremes at predetermined rates. It has been established that a book mass responds to environmental fluctuations so slowly that even large deviations over a few hours do not significantly impact book collections.

Status: Data from experiments with books were presented at two recent conferences. Publication of a manuscript by Frank H. Hengemihle and Chandru Shahani is anticipated in 1994. Experiments with manuscript boxes will be initiated in 1993.

3.4 Correlation between environmental conditions and permanence:

The conservator is often asked to advise on environmental conditions and their expected effect

upon the permanence of objects. Also, groups and individuals have proposed various environmental standards for storage, exhibition and shipping of cultural and historic objects. It is difficult to relate environmental conditions to anticipated rates of deterioration and assess the consequences of changing environmental parameters to meet building, climate, cost and other constraints.

This paper describes a simple graphical representation of the relationship of environmental factors to the permanence of hygroscopic materials. The graph can provide the conservator with immediate, quantitative estimates of the effect on permanence of different environmental conditions. Though paper is used as an example, the method is applicable to other hygroscopic materials such as wood, canvas, etc. Using temperature and relative humidity as environmental variables, examples are given of applications to problems of biological attack, annual cycling, cost effectiveness, comparability of proposed standards for storage and identification of areas for research.

Status: This work was presented by Donald K. Sebera at the Conservation in Archives International Symposium in Ottawa, Canada, in May 1988.

3.5 Effect of relative humidity changes on the flexibility of leather and parchment:

It is generally accepted that lower relative humidity levels are conducive to the longevity of paper-based materials. However, lower levels of relative humidity in libraries and archives can cause irreparable harm to leather bindings and to parchment if they become too dry and inflexible. Besides the danger of physical damage from bending and flexing of such materials in a dry state, excessive dryness can lead to a point of no return, where the lost moisture, and therefore flexibility, cannot be retrieved even upon humidification. Therefore, to be in a position to define optimal environmental conditions for long-term storage of paper, as well as leather and parchment, we need to understand the effects of relative humidity changes upon the flexibility of leather and parchment, and also their moisture-loss and regain characteristics. Data gathered thus far suggest that leather and parchment are appreciably more adaptable to changes in relative humidity conditions than is generally believed. However, any laboratory study of animal skins must suffer from the lack of any uniformity even within the same skin. Also, the system changes constantly as a direct result of the study. For example, the process of measurement of flexibility itself makes the material increasingly flexible. Therefore, any conclusions drawn from this investigation will suffer from inherent limitations.

Status: This work has been completed and may be published in 1993/4 by F. H. Hengemihle, S. B. Lee and C. J. Shahani. Preliminary data were shared with a NISO committee engaged in formulation of a standard for environmental conditions in libraries and archives.

3.6 Effect of different gaseous environments on permanence of paper:

The effect of a variety of microenvironments, ranging from inert (argon) to aggressive (sulfur and nitrogen oxides) on paper permanence are being studied as a function of relative humidity. Papers contaminated with copper and iron are also included in this study, since an inert environment appears to offer the least invasive solution for inhibiting transition metal-catalyzed degradation of paper.

Status: This work by Sang B. Lee and Chandru Shahani is at an early stage of progress, and is scheduled for completion by 1994.

3.7 Stabilization of acidic photographic film by alkaline paper inserts:

On the basis of preliminary experimental data developed at the Image Permanence Institute of Rochester, NY, a project was undertaken to investigate the potential for stabilizing deteriorating acetate and nitrate film by the introduction of an alkaline paper within its existing housing.

Status: This project has been in progress under contract at the Image Permanence Institute, and is scheduled for completion in 1993.

4. Effect of Paper Composition on its Stability

4.1 Effect of deacidification agents on papers contaminated with traces of copper species:

128

It is an established fact that the presence of even very small concentrations of copper and iron in paper can drastically reduce its life. In work published a few years ago, we established that neutralization of acidic species in paper, even without an alkaline reserve, can retard the degradative effect exerted by iron and copper contaminants. Recently, this work was extended to study the effect of different deacidification agents on the copper-catalyzed degradation of paper. The effect of some aqueous and non-aqueous deacidification treatments on the accelerated aging of copper-doped paper was investigated. The effects of the Barrow two-step treatment with calcium hydroxide and bicarbonate solutions, and treatments with magnesium bicarbonate, zinc bicarbonate and methyl magnesium carbonate solutions were compared. Except for the Barrow two-step treatment, all other treatments were applied by an immersion process, as well as by a spray technique. It has been observed that the extent of stabilization of paper against copper-catalyzed degradation depends not only on the nature of the deacidification agent employed, but also the technique by which it is applied. The beneficial effect of a magnesium bicarbonate treatment was not due to any complex formation between copper and magnesium, as had been suggested by earlier workers. Instead, it was the bicarbonate ion that was responsible for extracting copper from paper, and thus stabilizing it. Thus, contrary to claims made by some proponents of magnesium-based mass deacidification systems, any deacidification agent which deposits magnesium species in paper does not necessarily stabilize paper against degradative processes catalyzed by copper. Thus, copper-doped papers are not stabilized by immersion in a methyl magnesium carbonate solution. On the other hand, almost any aqueous bicarbonate solution, including a sodium bicarbonate solution, can effectively solubilize and dislodge copper species from paper immersed in it. The same solution sprayed on to the copper-doped paper, does not extend its life significantly. In the spray treatment, the paper cannot shed its copper content.

Status: This work was presented at Symposium 88 at the Canadian Conservation Institute in 1988 by Frank H. Hengemihle and Chandru J. Shahani.

4.2 Effect of lignin content on the aging of paper:

The photolytic degradation of paper due to the presence of lignin, as exemplified by the yellowing of newsprint exposed to sunlight, has been the subject of considerable investigation. However, the effect of lignin on the aging of paper under storage in the dark is not well established. The immediate significance of this study is that at present, we require that all paper and board that we buy for use in archival storage of library materials be free of lignin. Such materials generally cost twice as much as comparable materials with a very small lignin content. Aside from this economic interest, there are more interesting and fundamental issues that need to be addressed. The chemical structure of lignin suggests that it can act as an anti-oxidant, and therefore exert a stabilizing influence on paper. Can it be possible, therefore, that small concentrations of lignin may contribute to the longevity of paper? Additional reasons for gaining a better comprehension of the effect of lignin on the permanence of paper obtain from the increased use of recycled paper, which may have an appreciable lignin content, and new trends in paper manufacture with the emergence of chemi-thermomechanical pulp (CTMP) and other related mechanical pulps with better physical properties than generally associated with newsprint. It has been established that such pulps can have an appreciably higher permanence in the presence of alkaline size and/or filler.

In initial experiments, test papers were impregnated with different concentrations of a modified lignin from a dioxane solution. These papers were then subjected to accelerated aging at 90°C and 50% relative humidity, and tested for fold endurance and brightness retention. This first exploratory study suggested that the aging of paper accelerates as its lignin content increases, although the rate of degradation slows appreciably in an alkaline environment. However, we do not consider this finding conclusive at this stage. This work is being continued with test papers in which pulps with and without lignin content are mixed in different proportions to vary the lignin content. This should be a more definitive study. The effect of lignin on alkaline papers will also be investigated. Accelerated aging under dark, as well as light conditions will be undertaken.

Status: This work by Sang B. Lee and Chandru Shahani is in progress. It is scheduled for completion late in 1994.

5. Analysis and Testing of Library Materials

5.1 Comparison of techniques for testing of weak paper:

Research workers investigating the permanence of paper often have a personal preference for tests used to measure the loss in strength of paper as it ages. With different laboratories favoring different testing techniques, it is not easy to compare experimental data, since no one has the resources to employ the full battery of available testing techniques on a routine basis. To resolve this issue, an exhaustive project has been initiated to compare the relative sensitivity of several physical and instrumental tests in the measurement of an incremental loss in the strength of test samples. This work will attempt to bring out the strengths of testing techniques that are best suited to monitor the aging of paper, and weed out those that are not sensitive enough.

Status: This work by Sang B. Lee and Chandru Shahani is scheduled for completion in mid-1993.

5.2 Application of gel permeation chromatographic techniques to analysis of aging in paper:

Traditionally, most research workers investigating factors influencing the permanence of paper have shown a marked preference for using physical properties of paper, such as tensile strength, fold endurance, tear resistance, etc., to quantify its degradation, rather than its chemical properties. This preference is generally ascribed to the fact that even small chemical changes, which can be hardly quantified, are accompanied by appreciably larger physical changes, that are easily measurable. Nevertheless, measurements of chemical change, such as degree of polymerization, copper number and carboxyl content are frequently made to provide a complete the picture of the degradation process. Changes in the degree of polymerization or molecular weight of cellulose are generally measured by time-consuming viscometric techniques to quantify the aging process in paper. However, a gel permeation chromatographic technique can yield much better insight into degradation of polymers than simple viscosity measurements. Some workers have used this technique to follow the degradation of cellulose. However, several parameters, including the chemical modification of cellulose, need to be established before GPC can be added to our repertoire of routine tools. In initial experiments we have nitrated the cellulose in paper to solubilize it. These experiments appear promising. At least two other methods of derivatizing cellulose need to be compared.

Status: This work by Frank Hengemihle and Chandru Shahani is in a preliminary stage.

5.3 Correlation of thermal analysis of paper with accelerated aging techniques:

This work extends published work by other authors who have tried with a fair degree of success to correlate the rate of accelerated aging of paper to the rate of its weight loss under increasing temperature conditions. If a thermal analysis technique can be routinely employed to estimate the stability of a paper sample, it can not only lead to an extensive saving in laboratory time, but also result in better standards for permanent paper than those that are practical today.

Status: Considerable progress has been made in this work by Frank H. Hengemihle and Chandru Shahani; it is expected to be completed in 1994.

5.4 A new accelerated aging technique:

Because of its faster rate, accelerated aging within a sealed, air-tight enclosure can be used instead of humid aging to save precious time, especially in the quality control testing of paper samples for their stability. It is possible that this accelerated aging technique can be incorporated into a future standard for permanent paper. However, the relevance of this accelerated aging technique needs to be demonstrated before it can be generally accepted. Degradation products from such an aging technique are being compared with those present in naturally aged paper. The extent of correspondence between the artificially and naturally aged samples will determine the outcome of this effort.

Status: This work by Sang B. Lee and Chandru Shahani is in progress.

6. Digital Technology Applications for Library Preservation

6.1 Electronic imaging platform:

An electronic imaging workstation is being designed and developed to experiment with various image capturing schemes and compression methodologies. This workstation will be a high end imaging system designed to accommodate a wide range of image capture, from small transparencies to large poster size images, bi-level and continuous tone and

color. JPEG and arithmetic encoding in addition to the CCITT compression schemes will be investigated. The platform will be used also for a number of pilot or research programs to demonstrate required image capturing schemes for optimizing the image quality.

Status: This project is scheduled to be initiated by Basil Manns late in 1993.

6.2 Preservation of audio collections: A needs assessment study:

Analog audio collections recorded on magnetic tape and on other fast-degrading, fragile media offer the potential for the simplest and yet the most effective application of digital technology in preservation of library and archive records. Yet, the solution to the audio preservation problem is far from simple. A needs assessment study is planned so as to lay a solid foundation for the development of practical and effective solutions.

Status: This study is in progress under contract.

6.3 Optical disk testing:

To encourage and foster the development of more stable optical disk media, and to further develop methodology for such testing, we continue to test optical disks for their longevity, and participate in various SIGs related to testing methods, longevity requirements, disk certification procedures, and other testing.

Status: This is an on-going activity that Basil Manns has undertaken.

6.4 Document understanding:

Development of some proposed changes or additions to the WAIS text standard to include a browsing protocol for on line image data bases has been initiated.

Status: Basil Manns presented a paper "Document Understanding," at a recent SPIE conference, and will continue this work in compliance with Open Document Architecture international standards.

Chandru J. Shahani has been directing preservation research at the Library of Congress since 1982. He started his career in library and archive preservation at the U.S. National Archives and Records Administration in 1978. His major interests include the permanence and aging of paper, photographic materials and synthetics used in a variety of information storage materials, and the effect of environmental factors.

SESSION IV

IMAGING MEDIA PRESERVATION

RESEARCH IN CONSERVATION AT THE NATIONAL ARCHIVES OF CANADA

KLAUS B. HENDRIKS, *NATIONAL ARCHIVES OF CANADA*

First of all, I should like to thank those people who invited me to participate in this meeting, in particular Dr. Chandru Shahani. It is a real pleasure to be in Washington, where so much exciting work is conducted in our field, at CAL, NARA, here at the Library of Congress, and other places. I also want to thank you for having so generously taken care of the necessary arrangements.

Although my short presentation is located under the heading of Imaging Technology, I will divide my remarks into two parts. One part will describe briefly our work in the field of photograph preservation. In the second part, I would like to talk to you about how our interest in the preservation of archival records media has shifted tc take on a wider role. I will present to you our thoughts on the preservation of paper and efforts to define the important question: *what constitutes a permanent paper?*

Until two and a half years ago, I was directing the work of a group of people that was known as the Picture Conservation Division. One of the Division's mandates was to preserve photographic images and, if possible, to restore those that had suffered damage. Realizing that there did not exist, as in other fields of conservation, an established body of knowledge on the conservation of photographs, we convinced our superiors that it might prove useful to do a few experiments on the side in order to learn more about the properties of photographs. Much of that experimental work was done by summer students, interns, and guest workers from other countries with whom we shared a common love for photographs and a common interest in their preservation.

We started out by assembling what published knowledge there was on the stability and preservation of photographs, and put it together in the form of a bibliographic data base known as PHOCUS. Access to the data base is now possible through the Getty Institute Conservation Information Network. We then set out to discover where the greatest deficiencies were in our knowledge on the preservation of photographs. Our work in the subsequent years, that is throughout the 1980s, focused on:

-the duplication of black-and-white negatives;
-the recovery of water-soaked photographs;
-the mechanism of image silver degradation, and specific sourc of such degradation;
-the restoration of discolored photographic prints in chemical solutions.

DUPLICATION OF BLACK-AND-WHITE NEGATIVES

We had satisfied ourselves that there was a real need to understand the sensitometric principles underlying the preparation of duplicate negatives from original black-and-white negatives. They are known to the photographic scientist as the principles of tone reproduction. There was not much original research involved here. We merely reviewed some concepts that were developed during the 1920s by Lloyd Jones, at Eastman Kodak, and E.G.Goldberg in Germany, and applied them to the duplication of negatives. If correct tone reproduction is to be achieved, the characteristic curve of the reproduced image must rise at an angle of 45° to the x-axis, or approximately so. The tangent of that angle is known as g, and at an angle of 45° it is one. If an original scene is to be reproduced tonally correct on a negative, the product of the two gammas (from the characteristic curve of the negative and from that of the positive print) has to be unity. Furthermore, only the straight-line portion of the characteristic curve produces correct tone reproduction, as the response of both the film or paper to light is non-linear in the so-called toe and shoulder regions. These are the regions of distorted tone reproduction. All that needs to be done now is to ensure:

-that the density range of the original negative (the one that is to be duplicated) be placed on the straight-line portion of the characteristic curve of the duplicating film;

-that development is controlled in such a way as to give a curve whose straight-line portion rises at an angle of about 45°.

If these principles are understood, it is pos-

sible to make duplicate negatives from original black-and-white negatives that are in every respect equivalent to the original, regardless of any specific film type. That is to say, prints can be made from the duplicate negative that are indistinguishable from those made from the original negative. This is true for contact prints or for prints made by enlargement at a moderate magnification. Differences become visible between a print made from the original negative and one made from the duplicate only at extreme magnification. I will illustrate this observation with an example. The conclusions from this work which was conducted with the assistance of Brian Thurgood, Fred Toll, and Douglas Madeley [*Journal of Imaging Technology* 12(4): 185-199 (1986)] are summarized as follows:

1. A duplicating film must be chosen that has an extended density range on the straight-line portion of its characteristic curve.

2. The duplicating film must be capable of accommodating the density range of the original negative on its straight-line portion.

3. The duplicating film must be capable of being developed to a gamma of approximately one.

4. The duplicating film must have fine grain and high resolution.

These requirements apply to both the procedure via an interpositive, or when using a direct duplicating film.

Regarding correct terminology, it is customary in the photographic manufacturing industry to refer to a negative from a negative as a *duplicate negative*. A negative resulting from photographing a print with the use of a camera is properly called a *copy negative*. We have strictly followed this terminology.

RECOVERY OF WATER-SOAKED PHOTOGRAPHS

Following repeated requests for advice on how to recover photographs that had been soaked in water after a catastrophe such as flood or fire, we set out to examine the behavior of photographic images toward water. To our knowledge, the first account on the freezing of water-soaked paper documents had been published only about a dozen years earlier, by Flink and Hoyer in 1969. Our approach to this work was guided by the outstanding experience gathered here at the Library of Congress, in particular by Peter Waters and his colleagues. Several hundred photographs were soaked in water under different conditions by Brian Lesser, the principal collaborator in this project. [*American Archivist* 46(1): 52-68 (1983)]. Their behaviour was observed, and after certain times they were dried in four different ways. In another experimental series, several sets of about 50 film and paper samples, cut to a size to fit barely into 10cm high stoppered glass vials, were left under water until the image was destroyed. The weak link of every photograph, without exception, was the gelatin layer. In some film samples it took 30 days for the gelatin layer to dissolve, break up, or simply to slide off the support. Most samples survived for at least a week. Film samples withstood the soaking in water better than prints which confirms that their gelatin layers are hardened differently from those in prints. The result of these experiments are summarized as follows:

1. Water-soaked photographs are preferably air- dried.

2. (a) Most water-soaked silver gelatinand dye gelatin photographs can be frozen.

(b) Freezing of water-soaked photographic materials retardsdeterioration and allows time to prepare for further salvage efforts.

3. The following materials **cannot** be frozen:

a) Photographs made by the wet-collodion process: wet collodion glass plates negatives, ambrotypes, tintypes.

(b) Color lantern slides made by additive processes, for example: Lumiere Autochrome plates, Agfacolor plates, Dufaycolor plates, etc.

(c) Daguerreotypes.

4. Water-soaked photographic records that have been frozen are either thawed and air dried, or freeze dried in a vacuum chamber (at below 0°C).

5. Water-soaked photographic records that have been frozen *cannot be thawed and vacuum dried at +4°C*. Gelatin layers will cause them to stick together.

6. Glass plate negatives made by the wet-collodion process should be kept in long term storage in such a way as to protect them completely from becoming immersed in water.

I should like to place some emphasis on the recommendation that photographic images made by the wet collodion process, such as wet collodion glass plate negatives, and the direct positives known as tintypes and ambrotypes that are made by a variation of the process, should not be frozen. They should not be immersed in water; once they have become water soaked, they cannot be freeze-dried. Since we did not include in our experiments either daguerreotypes or color plates made by any of the additive color processes, we cannot make any recommendations regarding their recovery after a flood.

SILVER IMAGE STABILITY

For many years, we were interested in the stability of the image silver itself. Much experimentation was done with various toning processes. Photographic prints so treated were exposed to atmospheres of hydrogen peroxide, hydrogen sulfide, acidic peroxide, and other aggressive gases. This work was of a qualitative nature, and while much of it remained unpublished, it nevertheless taught us knowledge about the behavior and reactivity of photographic images. These experiments assumed a more serious role after my laboratory was able to acquire a second-hand transmission electron microscope, the Model EM300 by Philips. It was built in 1962, and was 25 years old when we started using it. We had to learn how to prepare individual silver grains for viewing in the TEM and for the first time were able to study the effect of size and morphology of individual silver grains on image stability.

A schematic representation of the slow degradation of a processed silver grain in the presence of oxidizing substances was published by researchers from the Fuji Photo Film Co. Ltd. in 1984. It showed how individual silver particles, after their oxidation to silver ions, could migrate away from the original silver nucleus. These small particles form a cloud of either silver sulfide or colloidal silver around the silver grain. Although I later learned that Fuji had demonstrated that scheme to be correct using electron microscopy, we believe that original electron micrographs showing this migration of silver ions were first published by our laboratory. We could observe this form of degradation in both naturally aged and discolored prints, and also as a consequence of exposure of test prints to a hydrogen peroxide atmosphere in the laboratory. The process of disintegration of a processed silver grain is accelerated by elevated relative humidity and can be carried through to the complete destruction of the silver grain using hydrogen peroxide. In such a case, visual examination shows all image detail to be lost. The individual silver grain is destroyed irretrievably. However, if there is a residual nucleus left, the image can be restored using traditional bleach and redevelopment techniques, which will be described in more detail later on. These observations were performed by Lincoln Ross and Joe Iraci.

More than thirty years ago, hydrogen peroxide had been shown to be a potent oxidizing agent, capable of oxidizing image silver and so discoloring black-and-white photographs. Its use as a test agent for the resistance of such photographs towards oxidation is now described as a standard test for measuring the effectiveness of chemical conversion of silver images (such as toning) against oxidation.[1] Hydrogen peroxide is a good choice, since it is easily available, effective in its reaction with image silver, and has been shown to have a deteriorating effect on photographs in real life. Many other materials are capable of discoloring black-and-white photographs, and we have examined two of them. The heavy fading along the border of early paper prints on salted paper was suspected to have been caused by the use of animal glue in mounting the prints to album pages. This fading occurred frequently up to about 1850, for example, in copies of W.H. Fox Talbot's famous book *The Pencil of Nature*, or in portraits by the Scottish photographers D.O. Hill and R. Adamson. Four different adhesives, derived from natural products, two of plant origin ("pastes") and two of animal origin ("glues"), were applied in various concentrations to the back of photographic prints made by different processes. Prints included salted paper prints. This work, in collaboration with Rick Palmer, showed that only commercial animal glue was capable of discoloring the image silver. We further determined that the active ingredient in the glue was thiourea, which reacts in very low concentrations with image silver. It is the cause of edge fading observed in salt prints from the first decade of photography.

In another project to illuminate the effect of certain materials on silver image stability, we examined, with the assistance of Rüdiger Krall, the origin of fingerprints on black-and-white photographs. While active ingredients in fingerprints are often called "acidic oils", "oily sweat", "sweaty acids", etc., the reality is much simpler: one fingerprint, weighing approximately 10^{-4}g, consists of about 0.7 to 3% sodium chloride, the rest being water and traces of lactic acid and urea. Single drops of water of 0.01mL volume

containing from 0.5μg to 3.0μg sodium chloride per drop at a pH of 4.7 (pH of human sweat), were placed on prints made on Kodak Studio Proof Paper. Each produced yellow discoloration of image silver. Fingerprints on photographs are generally caused by the sodium chloride content in human sweat. A conversion of image silver to silver chloride is the most likely reaction to occur as a result of a fingerprint. The silver chloride so formed may print out when exposed to light, giving rise to the discoloration lines in the form of the ridges and valleys on the surface of the human skin. An exception are some rather pronounced fingerprints of a different, clay-type color, which are likely caused by individuals with residual processing chemicals on their hands during work in the darkroom.

These examinations have shown that only very small amounts of aggressive chemicals are necessary to cause visible discoloration in black-and-white photographic images. The amount of image silver, while varying throughout the technological history of photography and from one type of record to another, is in the range of 50-60 μg/cm². It is finely divided, finely distributed, and has a large surface-to-volume ratio, making it a reactive material. Degradation reactions of the image silver are fascinating because the amazingly small amount of silver present in a photograph requires only equally minute amounts of reactants to cause striking visual changes in the image that are described as fading or discoloration. Our studies have not only shown that the presence of an aggressive, oxidizing chemical is necessary to cause image silver degradation, but they also allow to arrange different photographic materials in an order of inherent stability relative to each other. That order is determined by their structure and the morphology of their respective image silver grains.

The resistance of photographic films and prints towards the effect of oxidizing chemicals *increases* in the following order: salted paper prints < albumen prints < chloride paper < bromide paper < negative films. *Salted paper prints* are the least stable, because the image silver in salted paper prints is the most reactive. Image-forming silver grains in these prints are smaller than in developed-out papers by a factor of about 100. Therefore they are much more sensitive towards reactive materials in comparison to developed-out prints. The lack of a separate binding layer (termed the emulsion layer in contemporary print materials) only reinforces this sensitivity, since the paper support is quite permeable for many oxidizing gases, such as hydrogen peroxide. The absence of such a protective layer further increases the potential for mechanical damage by abrasion. [Consequently, modern films and papers carry a separate layer as protection against abrasion coated on top of the image layer]. And finally, early photographs on salted paper were generally made using support materials of unknown quality with the concurrent uncertainty regarding their stability. *Albumen prints*, as the name indicates, carries the image particle inside a protective layer derived from the white of eggs, which increases image stability. *Chloride papers* and *bromide papers* are both developed-out prints with silver particles embedded in a gelatin layer, which are larger — and therefore less reactive — than those in salt prints and albumen prints. They enjoy the additional benefit of a baryta layer, sandwiched between the paper support and the image layer, that protects the image from impurities migrating through the paper support. Photographic *negative films* have traditionally had a requirement for high light sensitivity, which results in a comparatively coarse image structure and increased resistance to chemical attack.

GELATIN STABILITY

The attempt to restore discolored black-and-white photographs in chemical solution is not without intellectual challenge. Let me state at the outset that it is necessary to distinguish between such treatments and techniques that are properly called tools of the photographer that can be used to correct errors made during exposure and processing. I am referring here to techniques known as reduction (of density) and intensification. These terms refer to silver image density: techniques of reducing density generally *remove* some image silver, whereas intensification treatments either *add* silver to the existing image silver; change the morphology of the processed silver grains; or convert it into a compound or alloy, all having the result of increased density. Much discussion, not always guided by extensive knowledge, but often colored by personal bias, has been going on in our field on the merit and ethics of such treatments. There are some who believe that photographer's techniques generally have no place in the preservation and restoration of photographs which would include, amazingly enough, duplication and copying! We took a close look at various ways of treating discolored photographs in chemical solutions and decided to examine in detail some reactions known as bleach and redevelopment.

There has never been a shortage of formulae for such treatments; what was lacking were precise data showing which formula would be suitable as a restoration procedure. The principle of the reaction is simple: All image silver and silver salts present in the image layer as a product of degradation reactions are completely and uniformly converted to a silver halide.

The silver halide, in a second reaction step, is redeveloped into a black silver image. No image silver is removed and none is added. The basically simple reaction develops into a sequence of approximately fifteen individual steps when accounting for intermediate washing, clearing, hardening, and fixing steps. We soon found out that effective silver oxidation reactants, such as potassium permanganate, were also detrimental to the stability of the gelatin. We settled back for a while to study the stability of gelatin layers on photographic supports, and the effect of hardeners on gelatin. [with Brian Lesser, Jon Stewart, and Douglas Nishimura in *Preprints of the A.I.C. 12th Annual Meeting*, p. 52-62 (1984)]. A convenient way of monitoring the state of the gelatin layer is to measure its swelling and deswelling in aqueous solutions. We confirmed the elegant description of the behavior of gelatin towards water, given by S.E. Sheppard in 1927, which I would like to quote here:

> "If we put a piece of gelatin in water at moderate temperatures, for example at about 15°C, the gelatin will swell to a limited extent, as shown. If however, we raise the temperature much above this point, *the gelatin will go on swelling without limit and will ultimately take up all the water offered to it*, and the jelly will break up into very small pieces."

A swellmeter described by Green and Levinson in 1972 allows an observer to monitor the swelling behavior of gelatin in water. The more it swells, the weaker the gelatin becomes. It is necessary, therefore, to prevent excessive swelling of the gelatin layer in any attempt to restore a discolored black-and-white image in chemical solutions. That can be done by the use of hardeners, which have two effects on gelatin: hardening raises the melting point, and it decreases the rate of swelling of the gelatin layer. After we had obtained the mechanical blueprints for the swellmeter from the Eastman Kodak Company, we had the instrument built by a local precision mechanic. It allowed us to follow the state of the gelatin as it passed through a series of chemical solutions in the course of a restoration sequence. We were able to prevent excessive swelling with concurrent breakup of the gelatin layer.

RESTORATION OF DISCOLORED PHOTOGRAPHS IN CHEMICAL SOLUTIONS

A study of the swell curves obtained during the restoration procedure and a visual examination of the restored image attests to the success of the restoration technique. Potassium bichromate works well in the presence of hydrochloric acid, as does cupric chloride. Whichever bleaching agent is used, its residues and reaction products must be washed carefully from the print. The development in a fast working developer, usually in a strongly alkaline solution, is the critical step for the survival of the gelatin layer. Pre-hardening may help here, but more effective is immediate displacement of the developer by a hardening fixer, without going through a water rinse first. That prevents excessive swelling of the gelatin layer. A final treatment in a selenium toner provides a stable silver image. [Published with LincolnRoss in: *Preprints of the A.I.C. 16th Annual Meeting*, p. 99-117 (1988); and in: *Wiener Berichte über Naturwissenschaft in der Kunst*, Vol 4/5, 372-389 (1987/88); and elsewhere]. It seems important to us to mention the detailed studies that were necessary to develop a workable procedure. Despite the observation that many colleagues in the photograph conservation field frown upon the use of any chemicals in restoration treatments for photographs, we found the application of chemical treatments to be useful. A fine example is the removal of a silver mirror from glass plates with a 0.5% solution of iodine in absolute alcohol, proposed by E. Weyde. Excellent work was also published earlier this year by Jesper Johnsen in Copenhagen and Bertrand Lavédrine and Françoise Flieder in Paris. We have no doubt that treatments in chemical solutions will assume a greater role in the future in photograph conservation work.

HAND-COLORED PHOTOGRAPHS

To conclude the work on photographs, we recently completed a fascinating study on the properties of hand-tinted and hand-colored photographs, coupled with an examination of the colors and pigments used for such work. This project consisted of a practical part, during which three rare hand-colored

photographs from the collection of the "Höhere Graphische Bundeslehr-und Versuchsanstalt" in Vienna were restored, and a study that attempted to identify retouching and hand-coloring media suitable for silver-containing photographs on paper. Published with Sebastian Dobrusskin [in: *Preprints of the 9th Triennial Meeting of ICOM (Dresden)*, p. 249-254 (1990).] our literature search revealed that 19th century practitioners were aware of the ability of some pigments to bleach the image silver in black-and-white photographs. A list of about 60 pigments and watercolors was published in our article indicating their suitability for use in retouching or hand-coloring.

Our experience in the stability and preservation of photographic materials accumulated over the years resulted in the publication of a RAMP (Records and Archives Management Program) Study, published by UNESCO *[The Preservation and Restoration of Photographic Materials in Archives and Libraries: A RAMP Study with Guidelines*. UNESCO; Paris: 1984]; and a chapter entitled "*The Stability and Preservation of Recorded Images*" in *Imaging Processes and Materials - Neblette's Eighth Edition*. Van Nostrand Reinhold; New York: 1989. In the spring of this year, the National Archives of Canada and Lugus Publications in Toronto jointly published our manual, co-authored by Brian Thurgood, Joe Iraci, Brian Lesser, and Greg Hill, entitled: *Fundamentals of Photograph Conservation: A Study Guide*. Lugus Publications; Toronto: 1991. Earlier this year, the Conservation Research Division contributed three entries for the *Focal Encyclopedia of Photography, Third Edition* on: "*Image Permanence*", "*Restoration*", and "*Storage of Photographs*". The volume is to be published by Focal Press, an imprint of Butterworth Heinemann, in early 1993.

CURRENT CONCERNS: COOPERATION IN RESEARCH

Two years ago, a Conservation Research Division was established at the National Archives of Canada. While in previous years, I could essentially choose myself in which area my laboratory would perform experiments, the work plan for the new Division, which is exclusively devoted to research in conservation, is determined by a Conservation Research Advisory Committee. The purpose of this committee is to review and approve research proposals submitted by the various Divisions in the National Archives. The proposals reflected the awareness of archivists in our institution of the current concerns in the preservation of their holdings: the instability of cellulose ester films; the need for toning of microfilm; the properties of manuscript boxes for the long term storage of written paper documents; and the stability of paper copies made by now obsolete office copying technology, such as Verifax, Electrofax, or the Agfa Copyrapid process. Foremost on the list of suggested research projects were:

-criteria for the evaluation of deacidification treatments;

-an evaluation of existing mass deacidification processes; and

-an understanding of what constitutes permanent paper.

The three topics are closely interrelated. If we had a clear measure of permanence, it would enable us to evaluate the effectiveness of deacidification. Knowledge on which properties a paper must have in order to be classified as permanent would be helpful in writing either national standards or government-internal regulations for permanent paper. Precedents exist in either category. Here is a fine chance for cooperative research. Unfortunately, it is customary in preservation research not to study a certain problem if another person, or laboratory, is already engaged in research on that problem. The reason given is that duplication of effort, or overlapping of work, should be avoided for cost reasons. This attitude may lead to a situation where a laboratory has a virtual monopoly in examining a given field of study. That is generally not the case elsewhere in science. In most areas of research that is worthwhile to be pursued, several groups, sometimes hundreds of them, examine the same topics, because the expected rewards are enormous and because of the potentially spectacular benefits to mankind. Compared to other areas of research in the fields of medicine, biology, and physics, the results of research in conservation will most likely never be spectacular. Therefore, we might just as well decide to cooperate in areas of urgent concerns. The challenges facing archives and libraries are so enormous that sharing of expertise, agreement of test methods and their interpretation, and exchange of results have become necessary. It is currently difficult to avoid the impression that preservation research is driven by motives other than a plain search for the truth. If the availability of funds does not seem to be a problem, research is done in the same area by different players, following different rules, with the inevitable consequence of almost contradictory results.

Studies on the stability of cellulose acetate films are a case in point. In the first issue of this year

of the *Journal of Imaging Science and Technology*, January/February 1992, two articles discuss the stability of cellulose triacetate motion picture films. They were published by two different laboratories. One concludes that "the average archival life of films in an iron container is 35 years". The second study finds that a "minimum of 300 years of acceptable life is predicted for cellulose triacetate films". What is an archivist to make of such statements? There are other organizations examining the stability of cellulose ester films, the Image Permanence Institute in the U.S.A., for example, and there are further studies in Europe. It is now necessary to read these publications very carefully and to take a critical look at the test used, the data obtained, and the interpretation of the data.

CURRENT CONCERNS: THE DEACIDIFICATION OF PAPER

A similar situation exists in the area of deacidification of paper and proposed mass treatments to achieve that. Various suppliers and user institutions have different ideas of what is effective deacidification and how to measure it. To be specific, I wonder whether it is possible that the different interested parties could agree, for example, on:

-what should be the pH *range* of a deacidified sheet?

-what should be the *minimum* and *maximum* values for the alkaline reserve. [There are good reasons to establish an upper threshold value].

-how can the effectiveness of a deacidification treatment be measured? [Both Wei T'o Associates and the Library of Congress have used the ratio of the rate of the drop in folding endurance *after* treatment over the rate of the drop in folding endurance *without* deacidification as an indicator of the increased stability of the treated paper. What is the basis for this?]

If generally agreed upon criteria for the evaluation of deacidification requirements could be established, the library and archives communities will benefit from such agreement world-wide. It might not come as a surprise that during the very recent meeting of the International Congress on Archives (I.C.A.) in Montreal, which meets once every four years and this time attracted 2,700 participants, the message came through loud and clear that archives and libraries — just because they may belong to different administrations — can no longer afford to pursue separate paths in their preservation efforts. I think there was consensus that scarce resources need to be pooled and shared and used for the public good which these institutions represent. Since the process of deacidifying paper is one in which libraries and archives share an equally strong interest, a coordination of research and testing work in this field would have a positive impact on the preservation of our printed and written heritage.

CURRENT CONCERNS: THE PERMANENCE OF PAPER

Nowhere is a cooperation of national, regional, and academic repositories for books and written documents more urgent than in the area of defining permanent paper and setting standard specifications for it. Definitions given for permanence in various standards, such as ANSI Z39.48-1984; or ASTM 3290-90; or in the *draft* version of ISO DIS9706, vary considerably. Some common understanding of and agreement on the meaning of permanence might be useful. I suggest that the definition by TAPPI be adopted by representatives of user groups. Permanence (of paper) is defined by TAPPI as "the degree to which paper resists chemical action which may result from impurities in the paper itself or agents from the surrounding air". Durability, on the other hand is defined as "the degree to which a paper retains its original qualities under continual use". Permanence in the definition by TAPPI is a qualitative property. It does not attempt to determine a time period that a paper sheet must remain intact in order to be permanent. Nor does it explain a measurable end point beyond which a paper ceases to be permanent. These properties remain elusive. The best that can be done is to deduce from empirical observations the principal factors that determine the permanence of paper and, as a consequence of these factors, recommend a suitable composition with respect to fiber origin, sizing agents, and presence or absence of lignin.

Since cellulose is the principal ingredient in paper, it is helpful to study the contributions made in other related fields that focus on the properties of cellulose. Such contributions can be found in journals of biochemistry, textile research, forestry and plant physiology, pure carbohydrate chemistry and in the publications of paper science and technology.

The majority of articles dealing *directly* with the permanence of paper originates from scientists in government institutions (e.g., U.S. National Bureau of Standards), universities, and from research work performed in cultural institutions, such as archives and libraries. Publications dealing with the various testing methods and their interpretation with regard

to permanence are the most complex and sometimes controversial.

Specific requirements in standards can be either contents-based or performance-based. Precedents exist for both, and some current standards contain both of these requirements.

There are so many modifications and variables in papermaking that may affect the permanence characteristics of the final product that one could experiment for many years trying to evaluate each of these variables with regard to their effect on permanence. Many articles have been published for this reason that do not fundamentally advance our knowledge. It would be more useful to concentrate on only a few parameters that have been shown by experience to have a significant bearing on paper permanence. From a study of the available literature references, including existing standards and government specifications from various countries, the following variables appear to exert the major effect on permanence:

- a minimum caliper and grammage;
- the amount of a-cellulose present
- the presence (or absence) of an excess of alum (if the paper is sized with alum rosin);
- the presence (or absence) of lignin and groundwood;
- the retention of certain physical properties after accelerated aging.

Until perhaps thirty years ago, the principal requirement for a permanent paper was a high alpha-cellulose content. It was expressed by the demand that such paper be made from rags or cotton and linen fibers, because their resistance to chemical changes, as requested by the TAPPI definition for permanence, was known to be high empirically. During the past few decades, there was a gradual shift from an emphasis on the principal ingredients, i.e., the origin and quality of the cellulose, to the absence of acidic components and the presence of an alkaline reserve, usually calcium carbonate. Methods for testing the property of the cellulose have been replaced by simple strength measurements and the determination of the pH and the alkali reserve. Since the subject of permanent paper is of interest to so many institutions and organizations, perhaps here too it should be beneficial to examine together, and agree upon certain key questions, for which there are no definite answers. Some examples are:

☞ Is it necessary to determine the quality of the cellulose in paper by measuring the average degree of polymerization (D.P.) and the copper number?

☞ What is the effect of lignin on the permanence of paper? How much lignin can be tolerated in paper without affecting its permanence?

☞ Which of the available strength measurements are indicative of paper permanence? In particular, what is the role of folding endurance? Which initial values for various strength properties should be required as indicative of permanence and durability? What is the reason that ANSI Z39.48-1984 requests an average folding endurance in both directions at 1kg tension of thirty double folds? What is the reason that ISO DIS9706 requests a minimum tear resistance in any direction of 350mN for papers having a grammage of >70 g/m ^{2}?

☞ Is the retention of chemical and physical properties after accelerated aging an indication of permanence? What percentage of a property must be retained by the paper in order to qualify as permanent?

☞ Finally: which accelerated aging conditions should be used? Can an agreement be obtained on this point?

With several different standards for permanent paper in existence, in addition to government specifications, it surely would be helpful if the *user community* (archivists, librarians, preservation scientists) could combine their knowledge and experience

to develop a consistent view on what constitutes permanent paper.

Much of our recent work has focused on what constitutes permanent paper, how to develop criteria for permanent paper, and identify tests suitable for evaluating such criteria. For the past eighteen months, my Division has been engaged in a cooperative research project with the Pulp and Paper Research Institute of Canada (PAPRICAN) in Pointe Claire, Québec, on the subject of permanent paper. The result so far is a summary report that is currently circulated among the member companies of PAPRICAN. My Division has also submitted a draft of a Canadian standard for permanent paper to the Canadian General Standards Board (C.G.S.B.). It differs in several points from the existing standard mentioned earlier. As chairman of a Sub-Committee on Permanent Paper, reporting to the C.G.S.B. Committee 9/GP/5 on Printing and Writing Papers, I plan to discuss our draft standard at a meeting of the Sub-Committee later this fall. I am looking forward to some exciting discussions, but also to advice and suggestions from my colleagues assembled here today.

ENDNOTES

The purpose of this report has been to present an overview of preservation research work performed at the Conservation Branch of the National Archives of Canada. It is customary in normal publishing to quote literature references at the end of such a report. In this case, a reference list would show only the names of one group of author(s), which is hardly avoidable since this paper deals essentially only with the work of one laboratory. I have therefore chosen to incorporate literature references to our work in the main body of the text to avoid giving the impression that our laboratory was the only, or perhaps the principal, actor in this field. This is, of course, not the case. Many excellent articles on the stability of photographic images in color and black-and-white and their support materials have been published during the past 30 years by other organizations, in particular by staff members of the Eastman Kodak Company, Fuji Photo Film Co. Ltd., Polaroid Corp., Agfa AG, Konica Corp., the Image Permanence Institute, and of academic institutions in Japan, the U.S.A., Denmark, and France, and more recently, from the Conservation Analytical Laboratory of the Smithsonian Institute. We believe that we are familiar with most of the work published by these institutions, which has benefitted us greatly. I should like to acknowledge the numerous excellent contributions to our field made by these organizations.

1. ANSI IT 9.15-1992 - American National Standard for Imaging Media [Photography]. The Effectiveness of Chemical Conversion of Silver Images Against Oxidation — Methods for Measuring. *This standard currently exists as a draft version.*

Dr. Klaus B. Hendriks is the Director of the Conservation Research Division (CRD) at the National Archives of Canada. His interests include management of technical services to archives and libraries, and the preservation of both paper and non-paper materials. Current work in the CRD is focused on the permanence of paper and the stability of photographic film supports. Methods of deacidification of paper are also examined.

A SUMMARY OF RECENT RESEARCH AT THE IMAGE PERMANENCE INSTITUTE

JAMES M. REILLY, *IMAGE PERMANENCE INSTITUTE*

IPI is engaged in five areas of research related to the preservation of imaging media:

* Silver Image Stability
* Testing and Evaluating Storage Enclosures
* Air Pollution Effects on Microfilms
* Preservation of Nitrate and Acetate Base Film
* Dark Stability of Chromogenic and Silver Dye Bleach Color Microfilms

Silver Image Stability

Draft Proposed Standard ANSI 9.15 for Evaluation of the Effectiveness of Stabilizing Treatments for Silver Images

IPI has proposed the creation of a new ANSI and ISO standard. Its purpose is to provide a standard method to measure the effectiveness of chemical treatments that stabilize silver images. Toner treatments involving gold, sulfur, or selenium have long been known to improve resistance to oxidation, but there has been no objective way to determine if satisfactory protection has been achieved. The new standard contains two tests: the hydrogen peroxide fuming test jointly developed by IPI and Kodak,[1] and a simple dichromate bleach procedure. The peroxide fuming test has practical significance because many real-life cases of deterioration can be traced to this class of oxidant. The test is specific to attack by species such as peroxide and atmospheric oxygen.

The dichromate bleach test is a general, non-specific determination of the extent to which the silver image has been converted into a stable, non-oxidizable substance such as gold, silver sulfide, or silver selenide. By measuring the density of the image before and after the dichromate bleach procedure, an estimate can be obtained of the extent to which the silver image has been chemically converted into a resistant compound. (The dichromate bleach removes metallic silver but leaves gold, silver sulfide, or silver selenide unaffected.) The ultimate in stability is achieved when there is no change evident in the image after the peroxide test and when the bleach test demonstrates 100% conversion of silver into a stable compound.

Because very high conversion levels usually result in a change of image color or density, conversion levels used in practice are typically less than 100%. However, unconverted metallic silver is still subject to oxidation by atmospheric oxidants such as ozone or nitrogen oxides. Thus, too low a conversion level would mean that an image is vulnerable to serious information loss due to oxidation. In the new draft proposed standard, the minimum acceptable degree of conversion is 65% (measured as Status A blue transmission or reflection density.) this was based on IPI's experience with microfilm, where bleached films having approximately 65% conversion to silver sulfide were used to make acceptable prints and duplicate films.[2]

IPI SilverLock™ Image Protection

SilverLock™, IPI's polysulfide treatment to improve the oxidation resistance of silver images, has been evaluated for use on pictorial films, cinema films, graphic arts films, and photographic papers.[3] Originally developed with microfilm in mind, SilverLock™ has proven to be generally useful with all types of conventionally processed silver photographic media. While optimum treatment times and temperatures do vary for different products, to date IPI has found that polysulfide treatment is successful in conferring oxidation resistance on many different product types and brands.

TESTING AND EVALUATING STORAGE ENCLOSURES

Extensions and Improvements to the Photographic

Activity Test (PAT) of ANSI Standard IT 9.2

IPI has continued to develop and improve methods to evaluate the chemical interactions between storage enclosure materials and photographs. New or improved methods have been developed for specific enclosure components such as inks, adhesives and plastics, as well as for interactions with specific products such as chromogenic color and diazo microfilm. With the sponsorship of Eastman Kodak Company, a significant new test method has been devised for photograph album pages. All these have been proposed to ANSI-approved committee IT9 for inclusion in ANSI standards. IPI has also proposed that the Photographic Activity Test, which has in fact become a family of related tests, be removed from IT9.2 and made it s own separate standard.

Changes to the "Basic" PAT

One significant alteration has been proposed in the "basic" PAT to remedy a situation where a physical effect could be misinterpreted as evidence of a chemical interaction, causing a harmless enclosure to fail the PAT. Glass, inert plastics such as uncoated polyester, and even some dense, smooth papers tended to cause high levels of fading (relative to filter paper controls) in the colloidal silver fade detector. Such effects were clearly physical and not chemical in nature; for example, a paper product which can cause excessive fading when used as a smooth, highly-calendered sheet performed very well when carefully re-pulped into a hand-formed sheet. It was apparent that in certain cases products had failed the PAT which likely would not interact chemically with photographs.

A program of experiments showed that the problem could be corrected by always inserting a layer of filter paper between the enclosure to be tested and the colloidal silver fade detector. This did not suppress the "signal" of harmful chemical interactions — known bad products still failed the test — but it did remove the false signal produced by having a smooth, dense surface in contact with the detector. Modifying the "basic" test in this way brought it into line with the approach used in testing inks and adhesives, where by necessity a layer of filter paper is used between the material and the detector.

Color PAT and Diazo Microfilm PAT

The "basic" PAT is designed to explore chemical interactions between enclosures and black-and-white photographs, and the detectors used in the test are specially chosen to highlight possible effects on silver and gelatin. Other types of photographs (for example, chromogenic color prints) may have different reactions to a given enclosure material. Different detectors, incubation conditions, and pass/fail criteria may be needed to evaluate enclosures for such products. IPI has developed a "color" PAT which parallels the basic test in approach, but which uses a 60°C incubation condition and a third detector consisting of the color material of interest. Another such product-specific PAT which IPI has proposed concerns diazo microfilm. In this case, the incubation conditions are the same as in the basic method, but the pass/fail criteria are tailored to the types of dye fading which occur in diazo films.

AIR POLLUTION EFFECTS ON MICROFILMS

With support from the National Endowment for the Humanities and the Andrew W. Mellon Foundation, IPI is investigating the effects of four common air pollutants (NO_2, H_2S, O_3, SO_2) on various types of films used in micrographic applications. Although the experimental program is only half completed, there are many exciting results so far. Ozone (O_3) is a very active oxidizing gas that poses some threat to silver-gelatin emulsions; it is a much greater problem, however, for the organic dyes used in color films and prints. The most sensitive materials appear to be diazo and chromogenic color products. In ozone atmospheres, silver oxidation is rapid at high levels of temperature, humidity, and gas concentration. Lower levels bring a corresponding lengthening of time for equivalent density losses. Ozone affects the gelatin in all products, and the binder may prove to be the most ozone-sensitive element for black-and-white materials.

In the sulfur dioxide (SO_2) to date there is one unusual but significant result. It appears that all of the materials are relatively unaffected by SO_2 except for the cyan dye to Eastmancolor negative film 5272. This dye is very sensitive to sulfur dioxide, even in low concentrations at ambient temperatures. Otherwise, SO_2 does not seem to be as aggressive toward photographic materials as might have been expected.

PRESERVATION OF NITRATE AND ACETATE FILM BASE

IPI is now in middle stages of it's second large research project on preservation of acetate and nitrate film base. With support from the Division of Preserva-

tion and Access of the National Endowment for the Humanities, IPI is investigating several aspects of this important preservation problem. Recently, IPI published Figure 1, which is based on data from the first acetate project in 1988-1991.[4] This graph summarizes the role of storage conditions in either promoting (or retarding) the onset of deterioration in acetate film base. Figure 1 shows the predicted amount of time required at a variety of temp./RH conditions for fresh triacetate film to attain a free acidity level of 0.5.

Free Acidity and the "Vinegar Syndrome"

The free acidity level of a cellulosic plastic film base is a very good overall indicator of its state of health. All cellulosic plastics (nitrate and acetate alike) are subject to chemical decomposition by acid hydrolysis, in which acetyl or nitro groups become detached, ultimately forming free acetic or nitric acid. Two things happen in the process: the measurable amount of free acidity in the film base increases, and eventually the entire film deteriorates, suffering shrinkage, brittleness, and emulsion damage. This form of deterioration is sometimes given the name "vinegar syndrome" because of the noticeable acetic acid odor which is present in degrading acetate film. The first reliable sign of this degradation process is usually the buildup of acidity in the plastic itself.

ANSI Standard IT9.1 provides a very sensitive method for measuring the free acidity in films, which involves scraping the emulsion, dissolving 1 gram of film in solvents, and titrating alkali into the solution in the presence of an indicator. The amount of alkali required to neutralize the solution (expressed as mL of 0.1N sodium hydroxide) is a direct measure of film base acidity. Data in Figure 1 was obtained using this method. Newly manufactured triacetate film typically has a free acidity value of 0.05 or less. Films with a free acidity level of 0.5 usually have some vinegar odor but are still usable. Very shrunken and degraded films may have free acidity values of 6 to 12.

Arrhenius Predictions of Free Acidity

Samples of a contemporary triacetate film preconditioned to 20%, 50%, and 80% RH, then wrapped tightly in aluminum foil and sealed in moisture-proof bags. Enough bags were prepared so that samples could be incubated for up to 12 different time periods at each of five different temperatures. The changes in free acidity over time were recorded, and then fitted to a mathematical model known as the Arrhenius relationship. This model assumes that the rate of chemical reactions (for example, the fading of dyes in chromogenic color films) depends in a predictable way upon temperature; if the data from accelerated aging test at high temperature meet certain mathematical conditions, then extrapolations about the rate of the reactions at room temperature and even under cold storage conditions can be made.

Although actual room-temperature keeping experience has tended to confirm the general accuracy of such predictions (this has been the case with dye fading), care should be taken not to rely too heavily on the specific number of years given in Arrhenius prediction. The best use of Arrhenius data is as a general quantitative estimation; for example, one can have confidence that a prediction of 34 years will be correct to within a decade or two, but the same degree of precision will not hold true when the prediction is for 500 years.

To create Figure 1, estimates of time required for fresh film to attain a free acidity value of 0.5 were calculated using the Arrhenius model. This was done for the range of temperatures from 150°F (65°C) down to 30°F (-1°C) Calculations were performed for samples incubated at each of the three RH's (20%, 50%, and 80% RH) used in the experiment. From this data an interpolated contour plot was created (Figure 1) which relates storage temperature and RH to the estimated amount of time it would take for fresh film to reach the 0.5 free acidity level. The contour line in Figure 1 are labeled with the time estimates; any point on the lines represents a combination of temperature and humidity conditions which would result in that particular time estimate.

Free Acidity vs. Useful Life

Figure 1 should not be taken to be an estimate of the useful life of acetate film, for several important reasons. First, the 0.5 acidity level represents the onset of vinegar syndrome, not the point at which film is too shrunken or brittle to use. It is a convenient index point to mark a phase of the degradation process where things will begin to happen rapidly from now on. To illustrate this, Figure 2 shows data from an accelerated aging experiment on triacetate film at 122°F (50°C), 80% RH. Free acidity is plotted against aging time in days. The shape of the curve shows that free acidity in the film base increases slowly at first, then increases very rapidly, eventually growing exponentially as a function of time. The 0.5 free acidity point is marked on this curve for easy reference; it occurs at a stage where the free acidity value is about

to rise dramatically, but has not yet done so. In a certain sense, it marks the end of a "grace period" where the acidity level has heretofore increased only slowly.

The chemical basis for the shape of the free acidity curve in Figure 2 is the fact that the reactions by which acids are released in cellulose acetate (or nitrate) are autocatalytic. The hydrolysis process which generates free acid is actually catalyzed by acids; in other words, the reaction feeds on itself by continually generating products which speed up the reaction rate. That is why once the vinegar syndrome begins it proceeds relatively rapidly to conclusion. From a preservation viewpoint, it is quite important to prevent film from ever reaching the autocatalytic point.

Storage Enclosures and the Vinegar Syndrome

A second fact to bear in mind about the time estimates in Figure 1 is that the actual behavior of acetate film in real life will be determined not only by the temperature and the RH, but also by the packaging and storage circumstances. Acetic acid is a volatile substance that will readily evaporate from film if it can. Allowing the acid to escape slows down the degradation reactions because the acid that evaporates from the film is no longer available to catalyze further deterioration. Experiments show that this factor can have a profound effect on reaction rate.[4] One can imagine two extreme cases: one where all the acid is trapped inside the film (this is the worst case, leading to fastest degradation), or the opposite, where all the volatile acid is allowed to evaporate.

Recalling that the data in Figure 1 were obtained from experiments in which a stack of non-interleaved films was tightly wrapped in aluminum foil, Figure 1 represents a situation which is close to the imagined "worst case." Therefore, in actual practice, film may take longer to reach the 0.5 free acidity level than the estimates given in Figure 1. However, in most real-life storage circumstance there are barriers to the ready escape of volatile acids; film that is tightly compressed in a file drawer or wound upon a reel inside a metal film can is much closer to the worst case of trapped acid that to the ideal of free escape.

One more aspect of Figure 1 to consider is the fact that the time estimates are based on continuous, steady-state temperature and RH conditions for the whole life of the film. In real collections a given film may have experienced a wide variety of storage conditions and packaging circumstances throughout its existence. Its present condition will be determined by the cumulative effects of the varying environmental circumstances it has experienced, and these can be very different from one piece of film to another. In collections having film of varied age and storage history, some materials will still have low acidity levels, while others may be approaching the autocatalytic point. For films which already have elevated free acidity levels, the time estimates given in Figure 1 may be too long.

Quantifying the Benefits of Improved Storage Conditions

Given all the ways in which Figure 1 may understate or overstate actual film life, what is its value? Most importantly, Figure 1 provides the best available scientific data on the required storage conditions to ensure that fresh acetate film does not become degraded through the vinegar syndrome. It helps us to understand why one collection experiences heavy losses in only 30 years, while another collection has almost no degradation among 70-year-old materials. Figure 1 is useful for evaluating the relative merits of storage areas for acetate film; sometimes a choice must be made among two or more storage rooms which have different temperature and RH characteristics. Data from Figure 1 can help to decide which one is the most advantageous for storing acetate film. For those considering building new vaults or upgrading their present storage conditions, Figure 1 provides a quantitative statement of the payback in increased film life expectancy that can be expected from investment in improved storage conditions.

DARK STABILITY OF CHROMOGENIC AND SILVER BLEACH COLOR MICROFILMS

With support from the J. Paul Getty Trust, IPI has investigated the dark stability of color microfilm products under a contract with the Commission on Preservation and Access, a preservation advocacy organization headquartered in Washington, D.C. Microfilming of brittle books, maps, and manuscripts is an important preservation strategy, but not all such materials can be adequately addressed by black-and-white microfilm.[5] The preservation community has raised questions about the stability of color microfilm products and their suitability as surrogates for the original collection material.

IPI's project has examined the dark keeping dye fading behavior, as well as various emulsion and support characteristics of the currently available color microfilm products. These include two families of film: Cibachrome silver dye bleach films and Kodak chromogenic color motion picture films. While the Cibachrome films are specially manufactured for the microfilm application, the chromogenic products are color negative and positive motion picture films which are not specially [produced for micrographics.

The project is not yet complete, but several trends are apparent. The dark keeping dye fading properties of the silver dye bleach films are exceptionally good; although these materials do not change enough in accelerated conditions to even allow for Arrhenius predictions to be made, it is reasonable to assume that they would not substantially change in two to three centuries of room temperature 50% RH keeping. The chromogenic films have considerably less inherent dye stability, though with cold storage they too can have such a life span. Data on the physical properties of the emulsion and supports of the two film systems will be reported in the next year.

REFERENCES

[1]P.Z. Adelstein, James M. Reilly, D.W. Nishimura, and K. M. Cupriks, "Hydrogen Peroxide Test to Evaluate Redox Blemish formation on Process Microfilm," *Journal of Imaging Technology*, Vol. 17, No. 3 (June/July 1991), pp. 91-98.

[2]James M. Reilly and Kaspers M. Cupriks, *Sulfiding Protection for Silver Images*. Final Report to the Office of Preservation National Endowment for the Humanities, (March, 1991)

[3]Christopher Gmuender, *On Black-and-White Paper Image STability Enhancement: Effectiveness of Toning Treatments on Silver Gelatin Prints Determined by the Hydrogen Peroxide Fuming Test*. MFA Thesis Report, Rochester Institute of Technology, 1992.

[4]P.Z. Adelstein, J.M. Reilly, D.W. Nishimura, and C.J. Erbland, "Stability of Cellulose Ester Base Photographic Film," *SMPTE Journal* (May, 1992), pp. 336-353.

[5]*Preserving the Illustrated Text*. Report of the Joint Task Force on Text and Image (The Commission on Preservation and Access, Washington, D.C., 1992.

James M. Reilly holds a Master's degree from the State University of New York at Buffalo. He is the director of the Image Permanence Institute at the Rochester Institute of Technology in Rochester, New York. IPI is an academic research laboratory with a staff of nine persons dedicated to image preservation and education of preservation professionals. It is cosponsored by the Society for Imaging Science and Technology. Mr. Reilly is the author of numerous technical articles on photograph preservation. he has written two books, most recently *Care and Identification of 19th Century Photographic Prints*, published by Kodak in 1986. Many museums, libraries, and archives have employed Mr. Reilly as a consultant on preservation. He has lectured widely in seminars and short courses around the world.

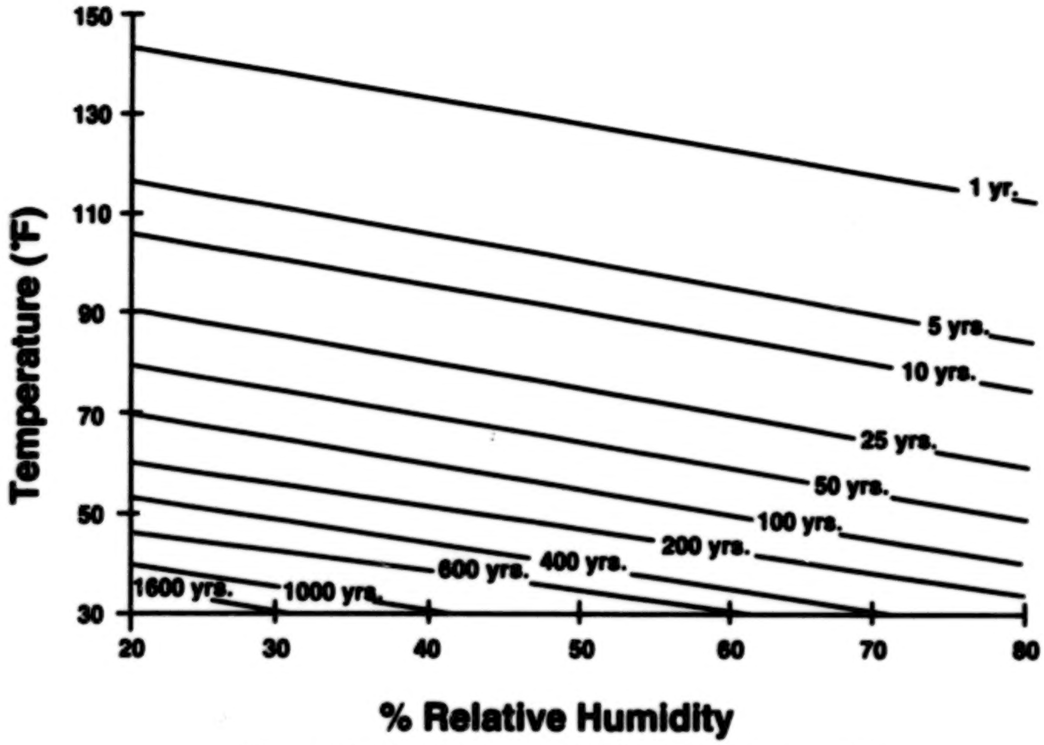

Figure 1. Predicted time to reach 0.5 acidity of triacetate film.

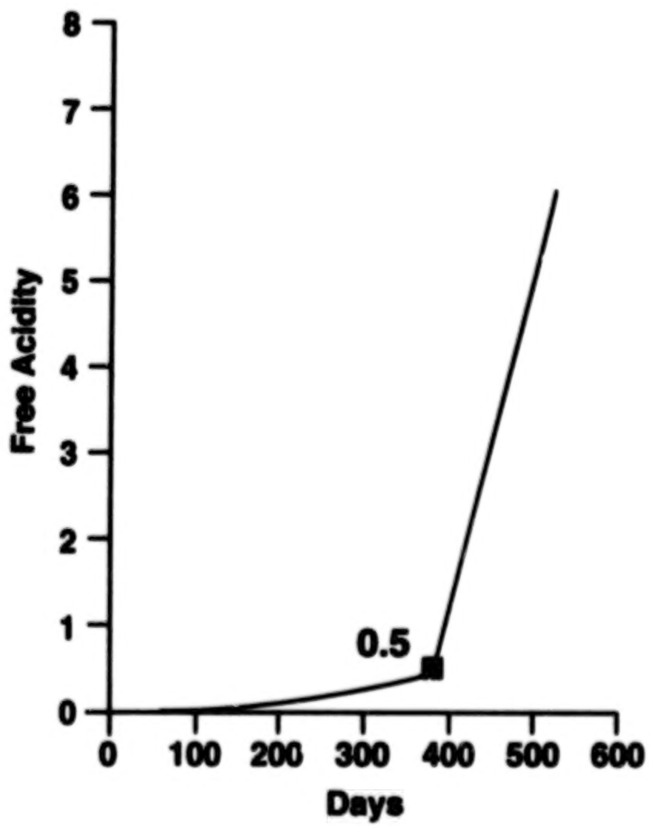

Figure 2. Free acidity of triacetate film incubated at 50°C, 80% RH.

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